AD-A199 163

DOT/FAA/CT-88/21

FAA Technical Center
Atlantic City International Airport
N.J. 08405

Experimental Guidelines for the Design of Turbine Rotor Fragment Containment Rings

James T. Salvino
Robert A. DeLucia
Tracy Russo

Naval Air Propulsion Center
Trenton, New Jersey

July 1988

FINAL

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

This document is disseminated under the sponsorship of the U. S. Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the objective of this report.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/CT-88/21		

4. Title and Subtitle

EXPERIMENTAL GUIDELINES FOR THE DESIGN OF TURBINE ROTOR FRAGMENT CONTAINMENT RINGS

5. Report Date

July 1988

6. Performing Organization Code

PE32

7. Author's

James T. Salvino, Robert A. DeLucia and Tracy Russo

8. Performing Organization Report No.

NAPC-PE-144

9. Performing Organization Name and Address

Commanding Officer
Naval Air Propulsion Center
P.O.Box 7176
Trenton, NJ 08628-0176

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

DOT-FA71NA-AP-98

12. Sponsoring Agency Name and Address

U.S. Department of Transportation
Federal Aviation Administration
Technical Center
Atlantic City International Airport, New Jersey 08405

13. Type of Report and Period Covered

Final
3/21/79 - 11/29/85

14. Sponsoring Agency Code

ACT-320

15. Supplementary Notes

PROJECT MANAGER: Bruce Fenton, Engine/Fuel Safety Branch
Federal Aviation Administration Technical Center

16. Abstract

Results of experimentation to determine design guidelines for turbine rotor fragment containment rings are presented in this report. The project consisted of two tasks. Task 1 was an investigation of the containment characteristics of cloth rings. Task 2 determined the engine casing thickness required for single and triple blade containment. This effort was conducted as part of the overall Rotor Fragment Protection Program.

17. Key Words

Rotor, Fragment Protection, Single
Single and Triple Blade Containment,
Rotor Failures,
Containment Rings,

18. Distribution Statement

Document is available to the U.S. public through the National Technical Information Service, Springfield, Virgina 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	36	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

PREFACE

This report has been prepared by the Naval Air Propulsion Center (NAPC), Trenton, New Jersey, under National Aeronautics and Space Administration (NASA) Defense Purchase Request C41581-B Modification No. 10 from the Lewis Research Center, NASA, Cleveland, Ohio 44135, and by direction of the Federal Aviation Administration. Mr. Robert Johns and Dr. Chris Chamis of the Lewis Research Center served as program monitors. Their contributions and help during this program are greatly appreciated. The authors would like to thank the Boeing Military Airplane Development Organization, a part of the Boeing Aerospace Company, for conceptual and analytical support in the fabrication of the cloth containment rings.

A-1

LIST OF ILLUSTRATIONS

LIST OF TABLES

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The experimental program supporting parametric studies of rotor fragment containment was developed and conducted by the Naval Air Propulsion Center (NAPC) under National Aeronautics and Space Administration (NASA) sponsorship. The formal reporting of this program was sponsored by the Federal Aviation Administration Technical Center (FAA) because of the relevance of the information to propulsion safety. The program objective was to develop guidelines for the design of optimum weight containment rings for gas turbine engine rotor fragments.

The test program being reported consisted of two tasks. Task 1 was an investigation of the containment of rotor sectors by cloth rings. Task 2 determined the engine casing thickness required for single and triple blade containment.

One phase of Task 1 was an investigation of the capabilities of Kevlar fabric as a lightweight containment device as opposed to 4130 steel which was reported in reference 2. Another phase of Task 1 was to compare the containment performance of rings manufactured from ballistic nylon fabric to rings manufactured from Kevlar 29 fabric. Task 1 consisted of a series of rotor fragment containment experiments in which rotors were modified to fail at their respective design speeds into three, pie-shaped fragments. These fragments impacted rings made from aluminum mandrels wrapped with either Kevlar 29 fabric or ballistic nylon fabric. The results of these rotor containment experiments indicated that Kevlar is superior to nylon but still considered inadequate for containing rotor fragments.

The objective of Task 2 was to determine the minimum engine casing thickness required to contain single and triple blade failures. This task consisted of a series of blade containment experiments in which Pratt & Whitney JT3D and JT8D turbine blades were modified to fail at 100 percent design speed and generate single and triple blade fragments. These fragments impacted steel rings whose radial thickness was varied until fragment(s) containment was achieved. The results of these experiments indicated that the minimum engine casing thickness required to contain a single JT8D blade is 0.187 inch and to contain a single JT3D blade is 0.250 inch. The test results showed that a minimum casing thickness of 0.375 inch is required to contain either a JT3D or JT8D triple blade failure. The results attained in Task 2 can be used as a model for containment devices used in any military or commercial aircraft having engines comparable in size to the JT3D or JT8D.

INTRODUCTION

The Rotor Fragment Protection Program was sponsored by National Aeronautics and Space Administration (NASA) and conducted by Naval Air Propulsion Center (NAPC). Formal reporting of the program was sponsored by the Federal Aviation Administration (FAA) Technical Center because of the relevance of the information to propulsion safety. The objective of the program was to develop guidelines for the design of lightweight devices that will be used on aircraft to protect passengers and the aircraft structure from lethal and devasting fragments generated by failure of gas turbine engine rotating components.

Previous reports published by NAPC in conjunction with NASA which document the progress of this program are listed as references 1 through 7.

This report presents the results of a parametric test program that was conducted to provide guidelines for the design of gas turbine rotor fragment containment rings.

METHOD OF TEST

Task 1. Test results presented in this report were obtained using basically the same equipment and techniques described in references 4 and 5. Figure 1 shows a typical test installation. The test procedure was as follows. The test rotor, modified to fail and produce particular shaped fragments at a specified speed, is connected to the air-drive turbine by an arbor. The containment ring under test is freely suspended by guide wires and is concentrically positioned around the test rotor. The axial, midsection of the ring is positioned to coincide with the test rotor's plane of rotation, and radial tip clearance between the rotor and ring is maintained at 0.50 inch (1.27 centimeters). The spin chamber is evacuated to 10 millimeters (mm) Hg pressure in order to reduce the aerodynamic drag on the test rotor and thus reduce the power required to accelerate the rotor to its failure speed. In order to record the fragment release speed, an impact-triggering strip is fixed to the inner diameter of the containment ring. When the fragment is released and makes contact with the inner surface of the ring, the low voltage signal of the triggering strip is interrupted, indicating the time of failure which is correlated to the speed at that time. The containment criterion for the turbine rotor fragment containment tests of Task 1 was as follows: The cloth ring is an acceptable turbine rotor fragment containment system if the fragments do not penetrate the outer layer of cloth.

Task 2. The blade containment experiments performed in Task 2 were conducted in a containment chamber that is 4 feet in diameter and 1 foot high. The test rotor, modified to release single or triple blade fragments, is connected to the air-drive turbine by an arbor. The test containment ring is placed at the bottom of the containment chamber and is concentrically positioned around the test rotor. The axial midsection of the ring is positioned to coincide with the test rotor's plane of rotation. The containment chamber is evacuated to 0.5 mm Hg pressure in order to reduce the aerodynamic drag on the test rotor and thus the power required to accelerate the rotor to its designed 100 percent speed. In order to record the blade release speed, an accelerometer, which detects vibrations in the chamber, is affixed to the chamber lid. The shock that is produced by the blade failure is detected by the accelerometer indicating the time of failure which is correlated to the speed of that time.

The containment criteria for the turbine blade containment tests of Task 2 were as follows: The engine casing is acceptable for blade containment if the damage from rotor blade failures is contained by the engine case; i.e., without causing significant rupture or hazardous distortion of the engine casing and/or the expulsion of blades through or beyond the perimeter of the engine case or shield.

DESCRIPTION OF TEST AND DISCUSSION

Task 1. Table 1 lists the rotor fragment containment experiments that were conducted to investigate containment capabilities of cloth rings. It also describes the materials used and the conditions of each experiment.

Four containment experiments were conducted to investigate the performance of Kevlar® 29 fabric as a lightweight containment device as opposed to 4130 steel. In three of these experiments, the General Electric T58 engine power turbine rotors were modified to fail at design operating speed into three equal pie-shaped fragments. In the fourth containment experiment, a General Electric T58 engine power turbine rotor was modified to fail at 100 percent design speed into six equal pie-shaped fragments. These experiments aided in the development of the final design configuration of cloth containment rings which was then used in the rotor fragment containment evaluations comparing the containment performance of rings manufactured with ballistic nylon to those manufactured with Kevlar 29. Eight of these nylon versus Kevlar rotor fragment containment tests were conducted using Curtiss-Wright J65 turbine rotors (figure 2) modified to fail at design speed into three equal pie-shaped fragments (figure 3).

The fragments from these rotor containment tests impacted containment rings made from lightweight aluminum drums, 1/32 inch thick, wrapped with either Kevlar 29 or ballistic nylon fabric. The material was folded on the bias and stitched with one, two, and three rows of Kevlar or nylon thread to give the best energy absorption capability. Figures A-1 through A-5 of the appendix define the Kevlar and nylon containment ring manufacturing technique. This technique was developed by the Boeing Company, who fabricated and wrapped the Kevlar containment rings used in the first eight rotor fragment tests (see figure 4). In the last four containment tests (three ballistic nylon tests and one Kevlar 29 test), the containment rings were manufactured by the Pioneer Parachute Company and wrapped by NAPC personnel. An example of the NAPC wrapping process is shown in figure 5. Once wrapped, the cloth containment rings can be seen in figures 6 and 7. A brief summany of the cloth containment ring characteristics is presented in figure 8.

Results of the rotor fragment containment experiments conducted in Task 1 are shown in table 1. In the Kevlar 29 evaluation experiments, only one of four General Electric T58 turbine rotors was contained. In the kevlar 29 versus ballistic nylon experiments, only two Kevlar 29 rings contained the fragments generated by a Curtiss-Wright J65 turbine failure and none of the ballistic nylon rings contained the fragments. Figures 9 and 10 are examples of the nylon and Kevlar fabric damage after uncontained failures. The results of these cloth containment ring tests indicated that Kevlar 29 is superior to ballistic nylon, but both are considered inadequate for rotor containment.

Task 2. Table 2 lists the blade containment experiments that were conducted to determine the minimum engine casing thickness required for single and triple blade containment. This table also describes the materials used and the conditions of each experiment.

To determine the minimum engine casing thickness, a series of blade containment experiments was conducted. In these containment experiments, blades from fully bladed JT3D (second stage) and JT8D (first stage) low pressure turbine rotors were modified to fail at 100 percent design speed (6850 and 8800 revolutions per minute (rpm) respectively) and impact containment rings of various thickness (figure 11) made from A-286 steel. (JT3D and JT8D rotors were chosen as representative of large turbine rotors in use today.) The blade containment experiment results reported herein were generated by single and triple blade releases. Single blade release is accomplished by appropriate notching of a blade causing it to fail at the rotor's 100 percent design speed. Figure 12 shows a single blade notch configuration. Triple blade release is accomplished by modifying the rotor, as shown in figure 13, causing three blades to separate from the rotor at 100 percent design speed. Several preliminary tests were conducted, using 304 stainless steel containment rings, to verify the appropriate blade notching configuration to be used in achieving blade release at design speed.

The actual blade containment experiments used containment rings made from A-286 steel with an axial length of 9 inches. The radial thickness of the containment rings was varied from 0.140 inch to 0.387 inch. To optimize testing and reduce cost, a test scheme (figure 14) was developed. This test scheme was designed as follows: An arbitrary ring thickness was chosen, based on engineering judgement, as the starting point, and a containment test was conducted. If containment was achieved, the containment ring thickness would be reduced and another blade containment test would be conducted. If containment was not achieved, the containment ring thickness would be increased for the next containment test. This process was continued until containment was achieved. The results of these blade containment experiments are presented in matrix form in figure 15. These results indicate that the minimum engine casing thickness required to contain a single JT8D blade is 0.187 inch and to contain a single JT3D blade is 0.250 inch. The minimum engine casing thickness required to contain three blades from either a JT3D or JT8D rotor is 0.375 inch.

Using this test data, a simplified formula has been devised whereby the thickness of the containment ring required to contain fragments of specified energy may be estimated. Since the blade containment tests were conducted with containment rings made from A-286 steel, the formula is valid only for this ring material. It is expected that variations in ring material can be expressed by changes in the formula constants. The formula is

$$t = .0014E^{.48}$$

where t = thickness of the A-286 steel containment ring, inches
E = kinetic energy of the fragment, in-lbs.

Figure 16 shows the test data points plotted as fragment energy versus containment ring thickness. The solid line in figure 16 is a plot generated from the formula above. It is being used as a conservative approximation of the minimum thickness required for an A-286 steel containment ring to be successful at the corresponding fragment energy. However, due to the limited number of test specimens used in developing this formula, exact containment ring thickness should not be derived from this relationship.

CONCLUSIONS

Task 1. Neither Kevlar® 29 nor ballistic nylon fabrics are adequate for rotor containment. However, Kevlar 29 did perform better than ballistic nylon in these tests.

Task 2. The minimum engine casing thickness required to contain a JT8D single blade failure is 0.187 inch and to contain a JT3D single blade failure is 0.25 inch. Both the JT8D and JT3D experiments required a minimum casing thickness of 0.375 inch for triple blade containment. Since the JT8D and JT3D turbine rotors are representative of most large turbine engine designs used in commercial aircraft, the results of this testing can be generalized for any turbine engine having blade fragment energies comparable to the JT8D and JT3D turbine blades.

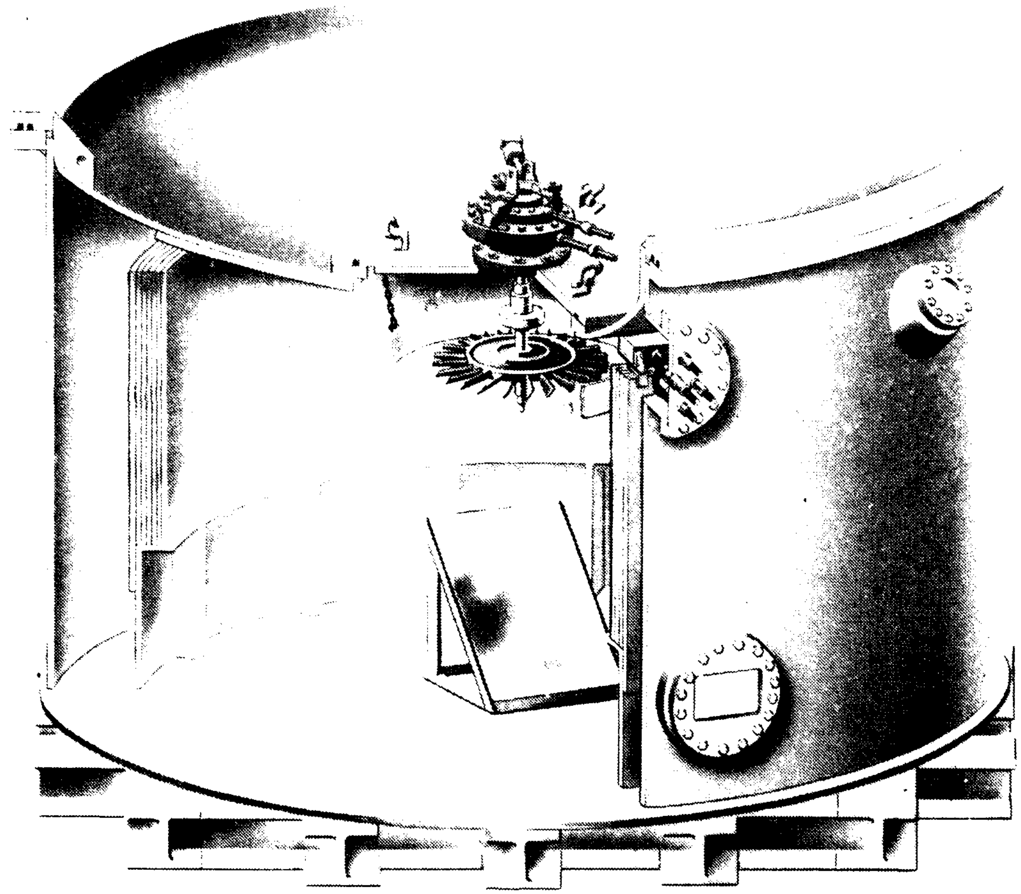
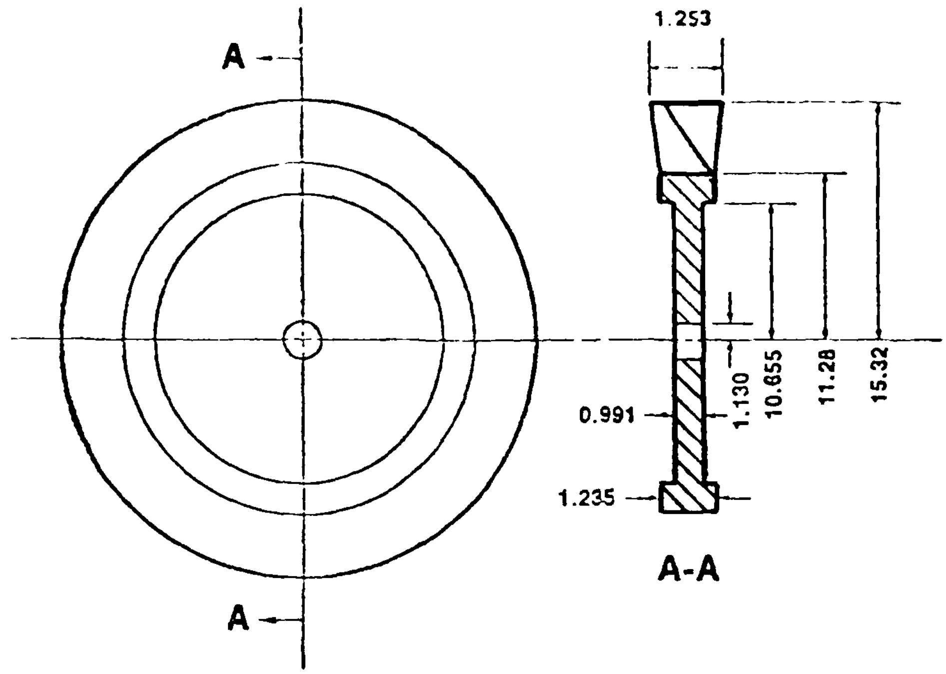


FIGURE 1. TEST SETUP FOR TASK 1



TYPE ROTOR : J-65 SECOND STAGE TURBINE (MODIFIED, UNSLOTTED)

ROTOR WEIGHT : 128 LBS (APPROX.)

ROTOR INERTIA : 9410 LB-IN² (NOMINAL)

	DISK	BLADES
MATERIAL :	17-22A FERRITIC STEELS	INCONEL 700
PROPERTIES :		
SU	142K PSI	148.5K PSI
SY	128.5K PSI	132K PSI
EU	18%	18%
HD	311 BHN	311 BHN

FIGURE 2. J65 TURBINE ROTOR CHARACTERISTICS

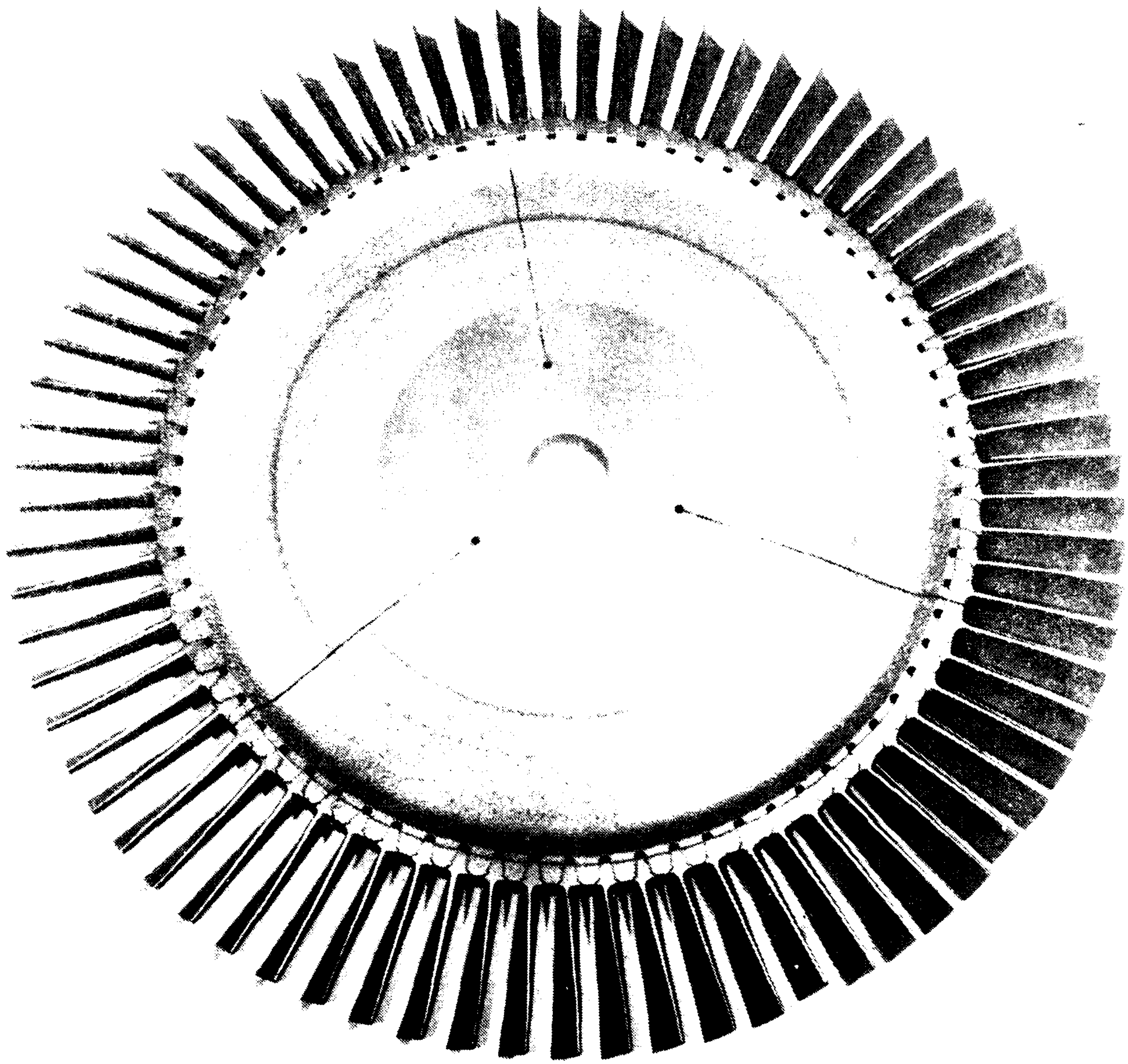


FIGURE 3. J65 ROTOR MODIFIED

T58 Rotors

Kevlar - Boeing - Four (4) Tests

1. No. 215 - 06/14/76 - Three (3) Fragments - Partial Containment
2. No. 218 - 09/02/76 - Three (3) Fragments - Contained
3. No. 219 - 10/19/76 - Six (6) Fragments - Not Containment
4. No. 220 - 12/07/76 - Three (3) Fragments - Partial Containment

J65 Rotors

Kevlar - Boeing - Four (4) Tests

1. No. 221 - 02/16/77 - Three (3) Fragments - Contained
2. No. 222 - 04/27/77 - Three (3) Fragments - Contained
3. No. 226 - 09/01/77 - Three (3) Fragments - Not Contained
4. No. 229 - 11/07/77 - Three (3) Fragments - Not Contained

Nylon - Pioneer Parachute Company - Three (3) Tests

1. No. 241 - 12/12/80 - Three (3) Fragments - Not Contained
2. No. 243 - 01/30/81 - Three (3) Fragments - Not Contained
3. No. 244 - 02/02/81 - Three (3) Fragments - Not Contained

Kevlar - Pioneer Parachute Company - One (1) Test

1. No. 245 - 02/04/81 - Three (3) Fragments - Not Contained

FIGURE 4. KEVLAR-NYLON TESTS

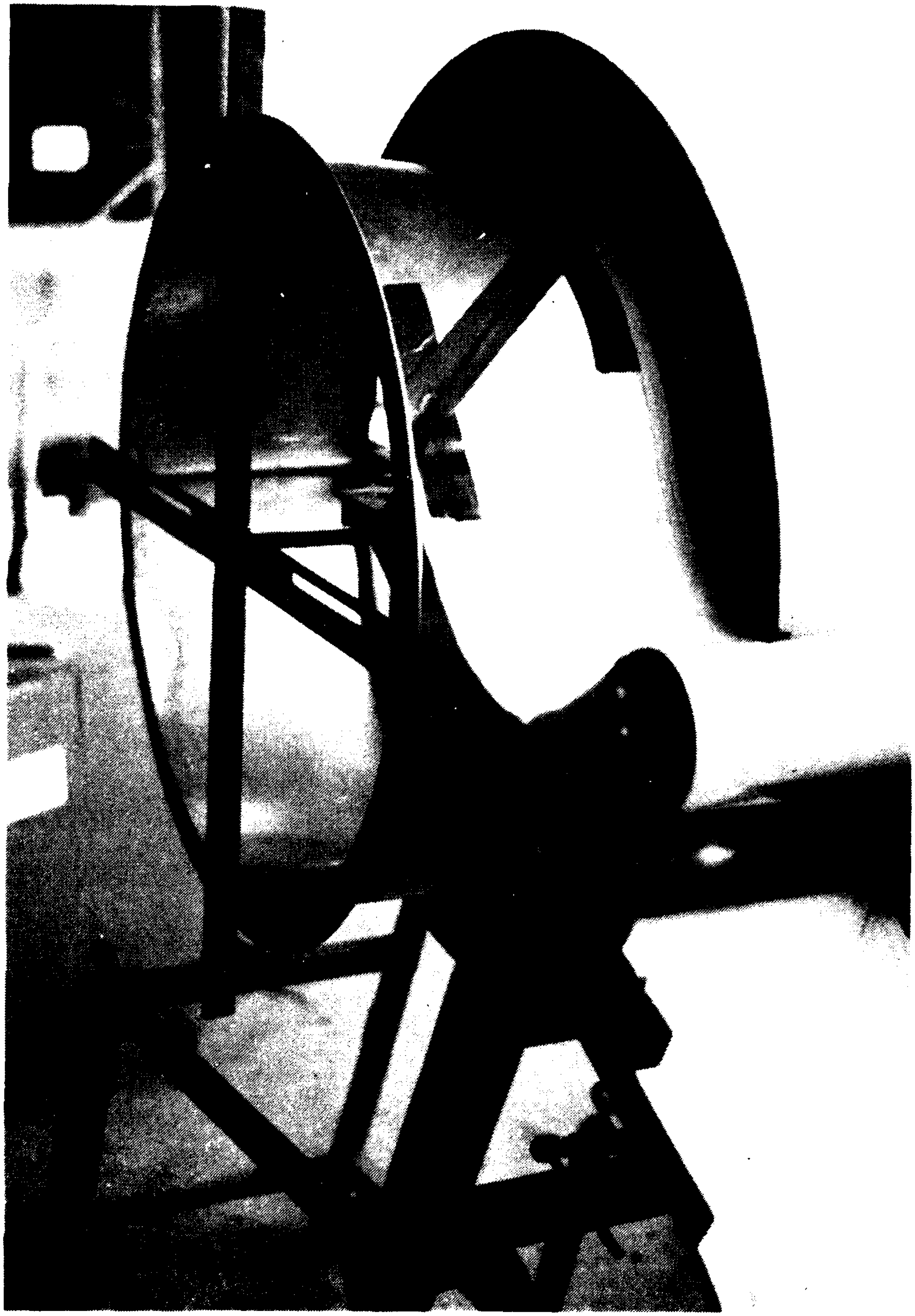


FIGURE 5. NAPC WRAPPING PROCESS

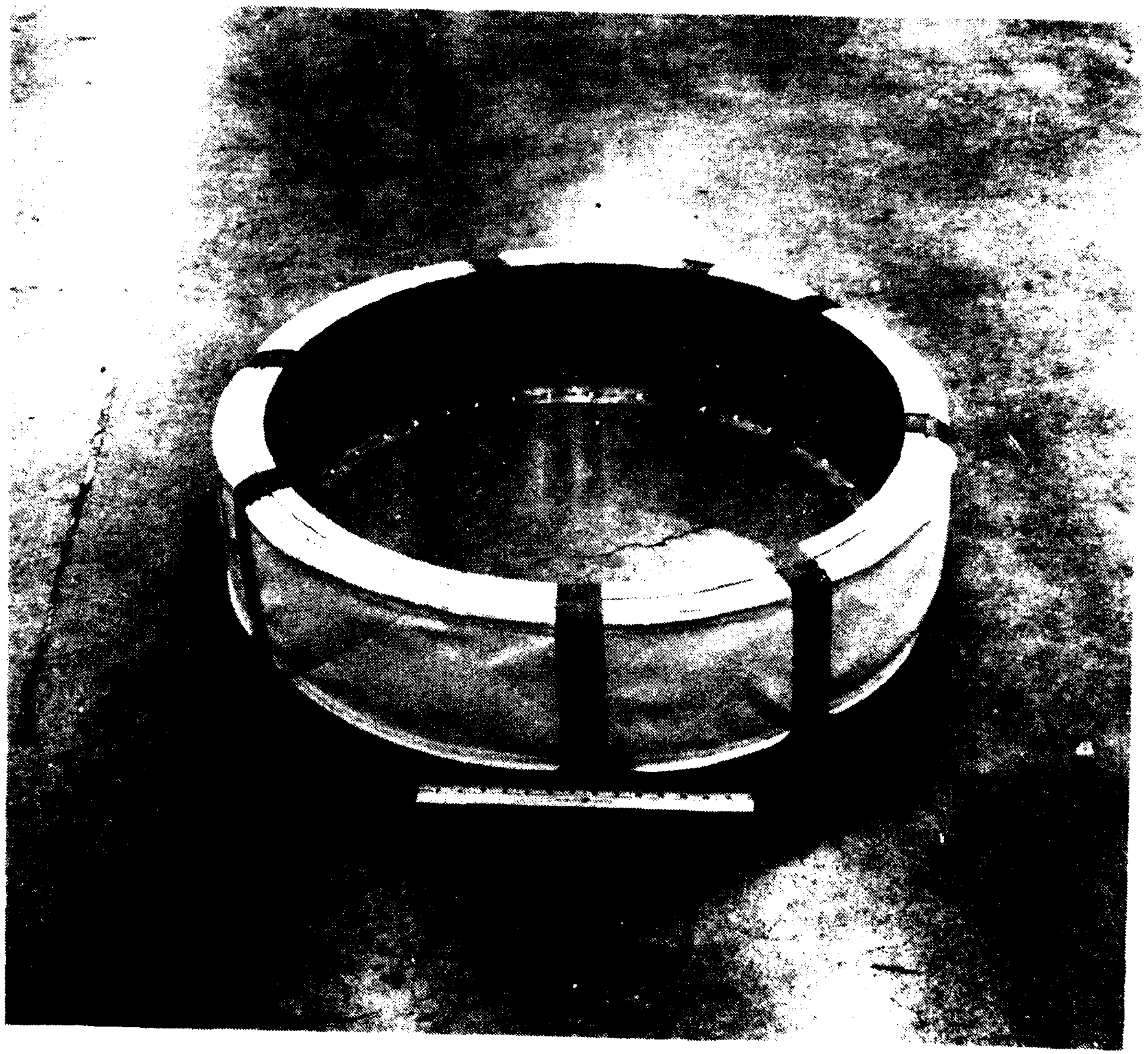


FIGURE 6. KEVLAR CONTAINMENT RING

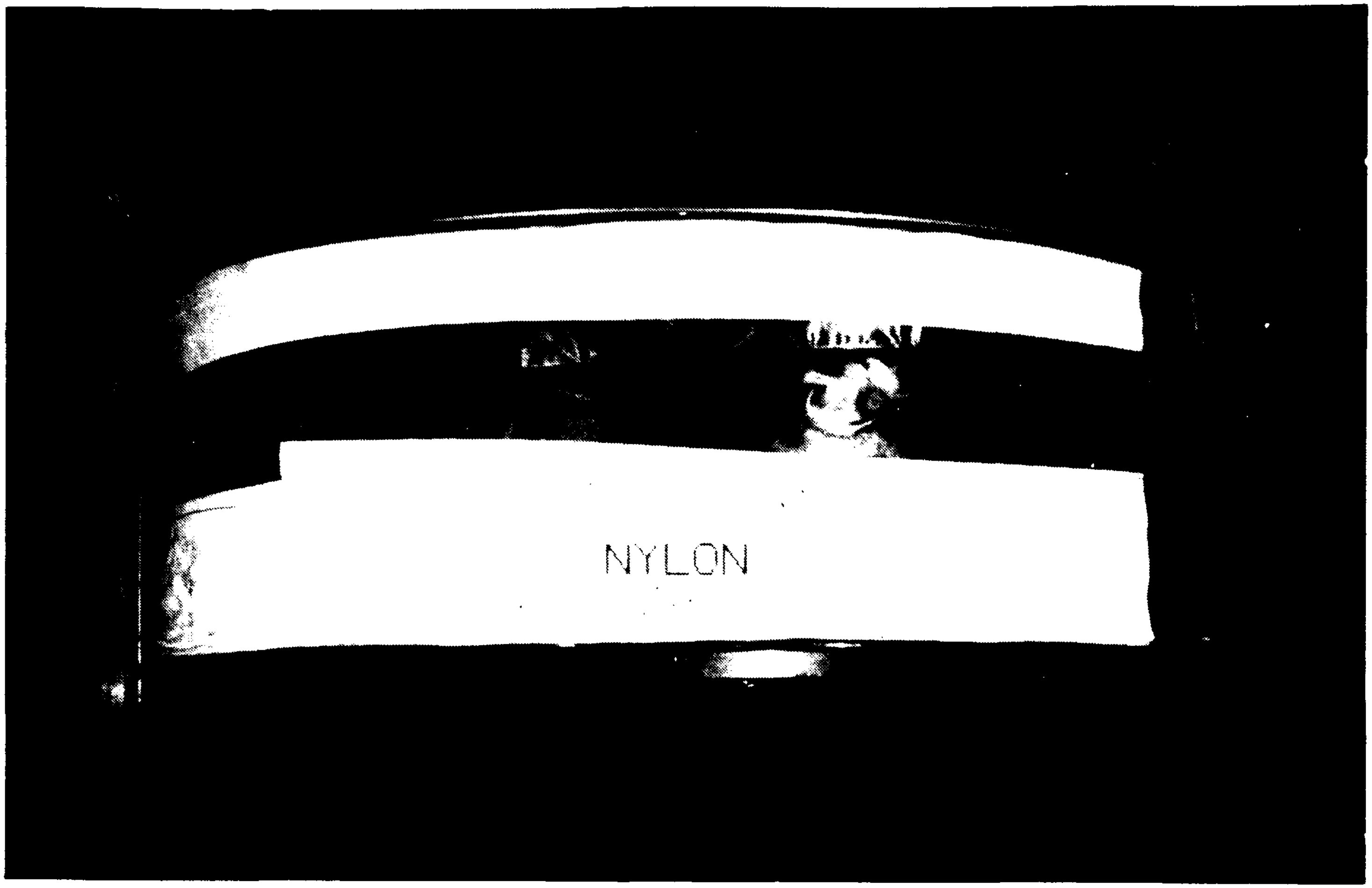


FIGURE 7. NYLON CONTAINMENT RING

MATERIAL	BALLISTIC NYLON	KEVLAR 29
ID	32"	32"
AXIAL LENGTH	12.5"	9"-12"
WEIGHT	65 LBS	55-71 LBS

FIGURE 8. CONTAINMENT RING CHARACTERISTICS

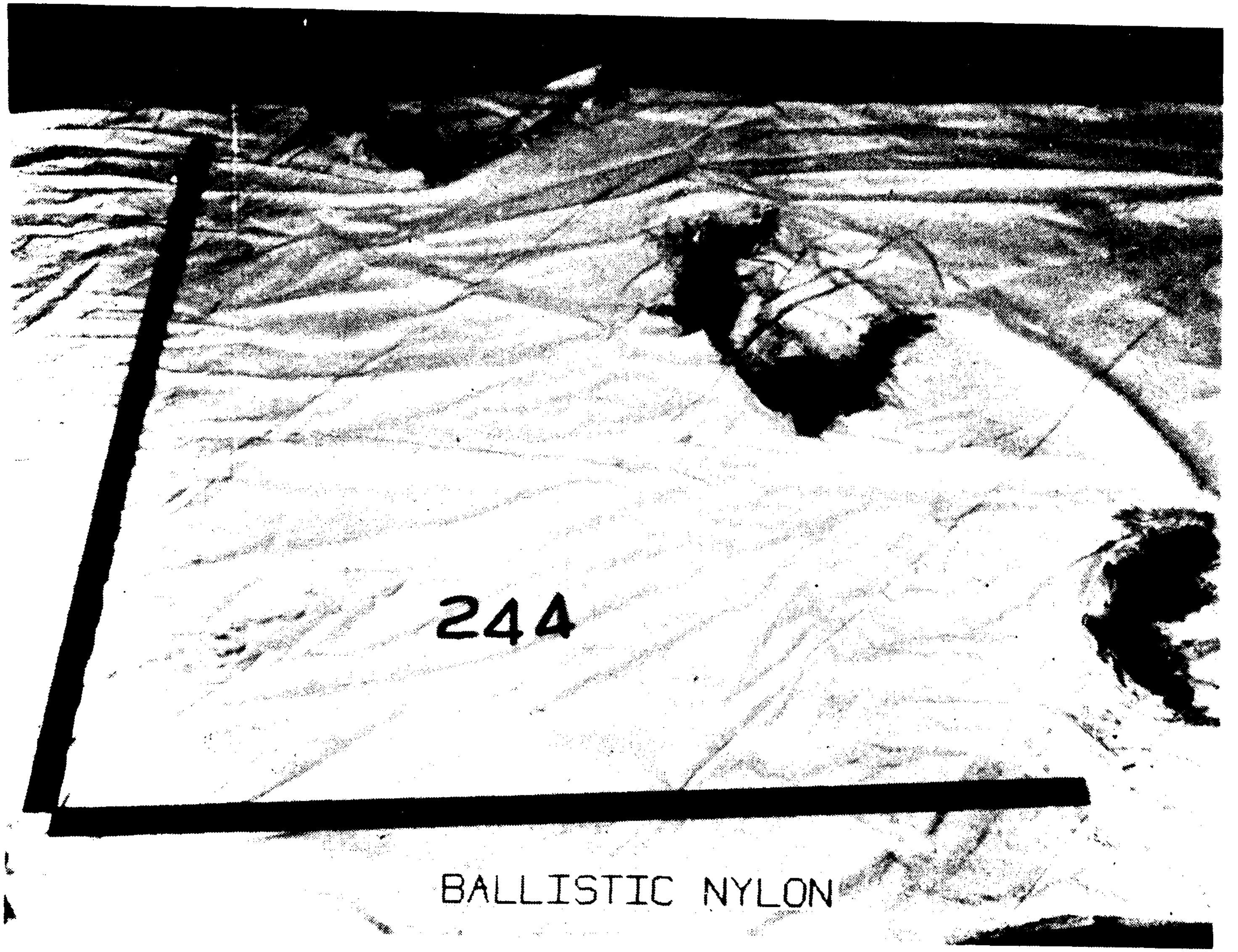
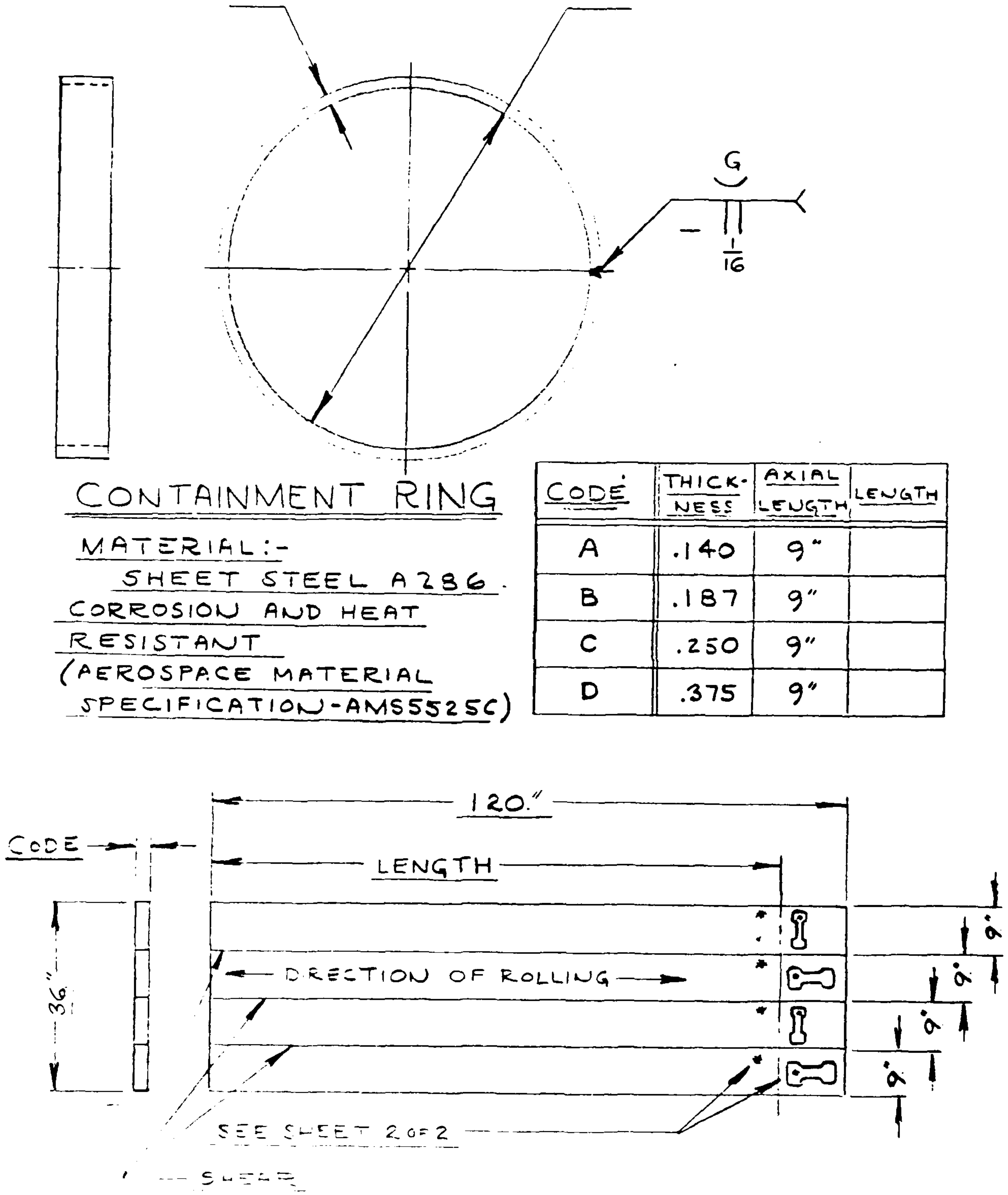


FIGURE 9. BALLISTIC NYLON UNCONTAINED FAILURE

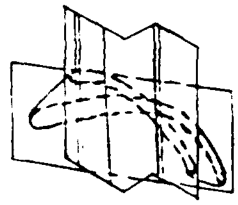
FIGURE 10. KEVLAR 29 UNCONTAINED FAILURE



CODE	THICK-NESS	AXIAL LENGTH	LENGTH
A	.140	9"	
B	.187	9"	
C	.250	9"	
D	.375	9"	

FIGURE 11. CONTAINMENT RING DESIGN

NOTE:- MODIFY BLADE AS SHOWN



REV NO.	A	B
A	.084	.385
B	.109	.372
C	.097	.378
D	.096	.379
E	.090	.382

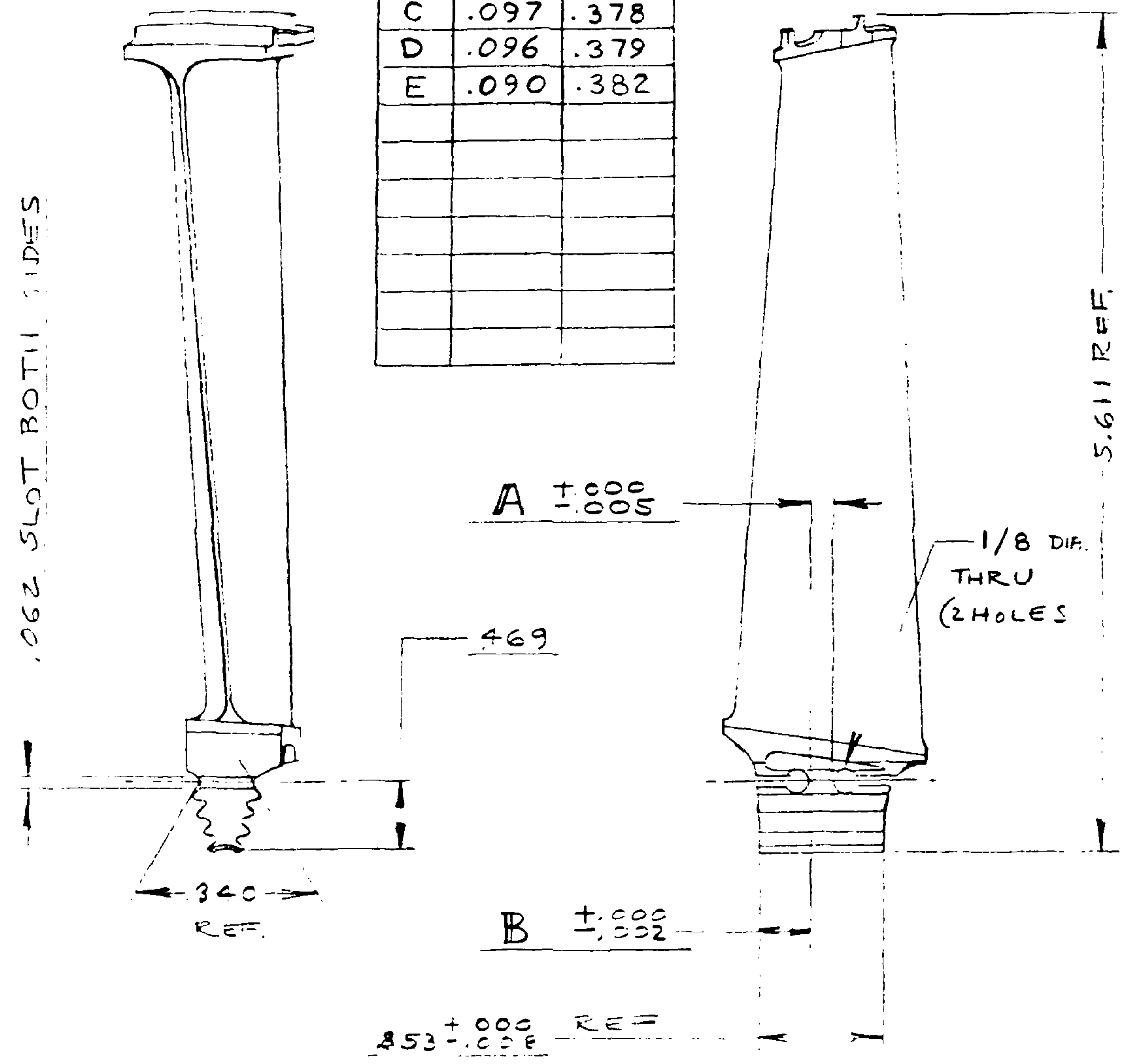


FIGURE 12. SINGLE BLADE MODIFICATION

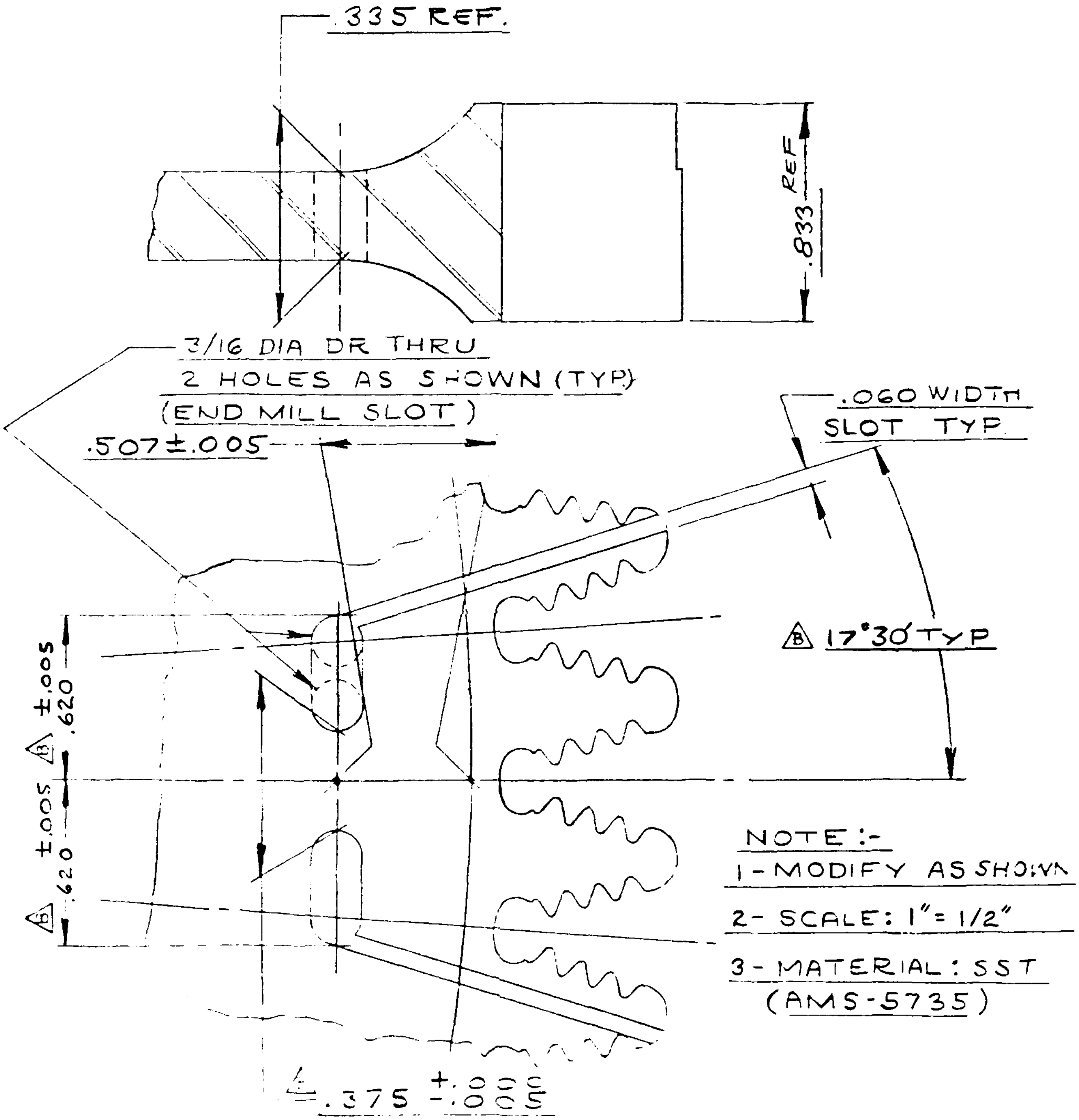
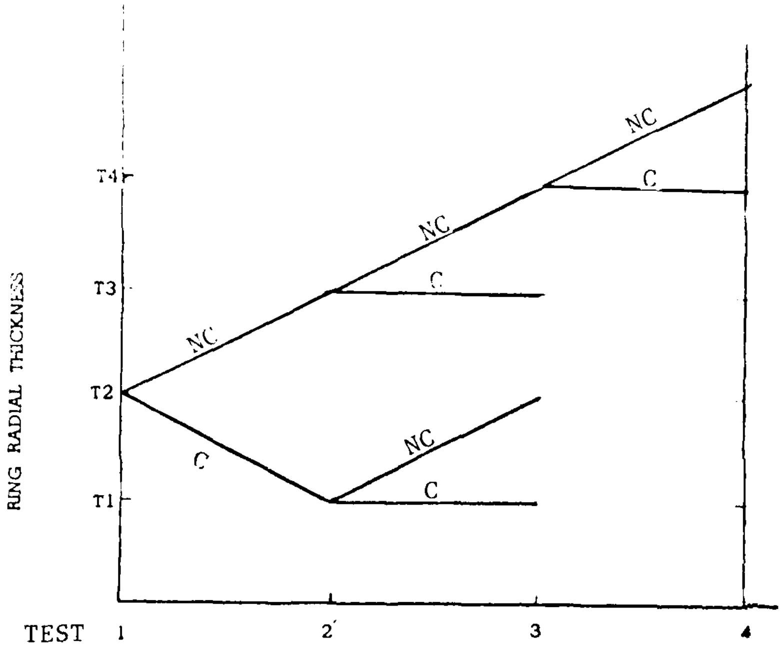


FIGURE 13. TRIPLE BLADE MODIFICATION



C – Contained
NC – Not Conta‹ned

FIGURE 14. TEST SCHEME FOR TASK 2

RING RADIAL THICKNESS (inches)	JT3D SB	JT3D TB	JT8D SB	JT8D TB
.140	NC		NC	
.187	NC C		C	
.250	C	NC		NC
.375		C		C

SB – Single Blade
TB – Triple Blade

C – Contained
NC – Not Contained

FIGURE 15. TEST MATRIX FOR TASK 2

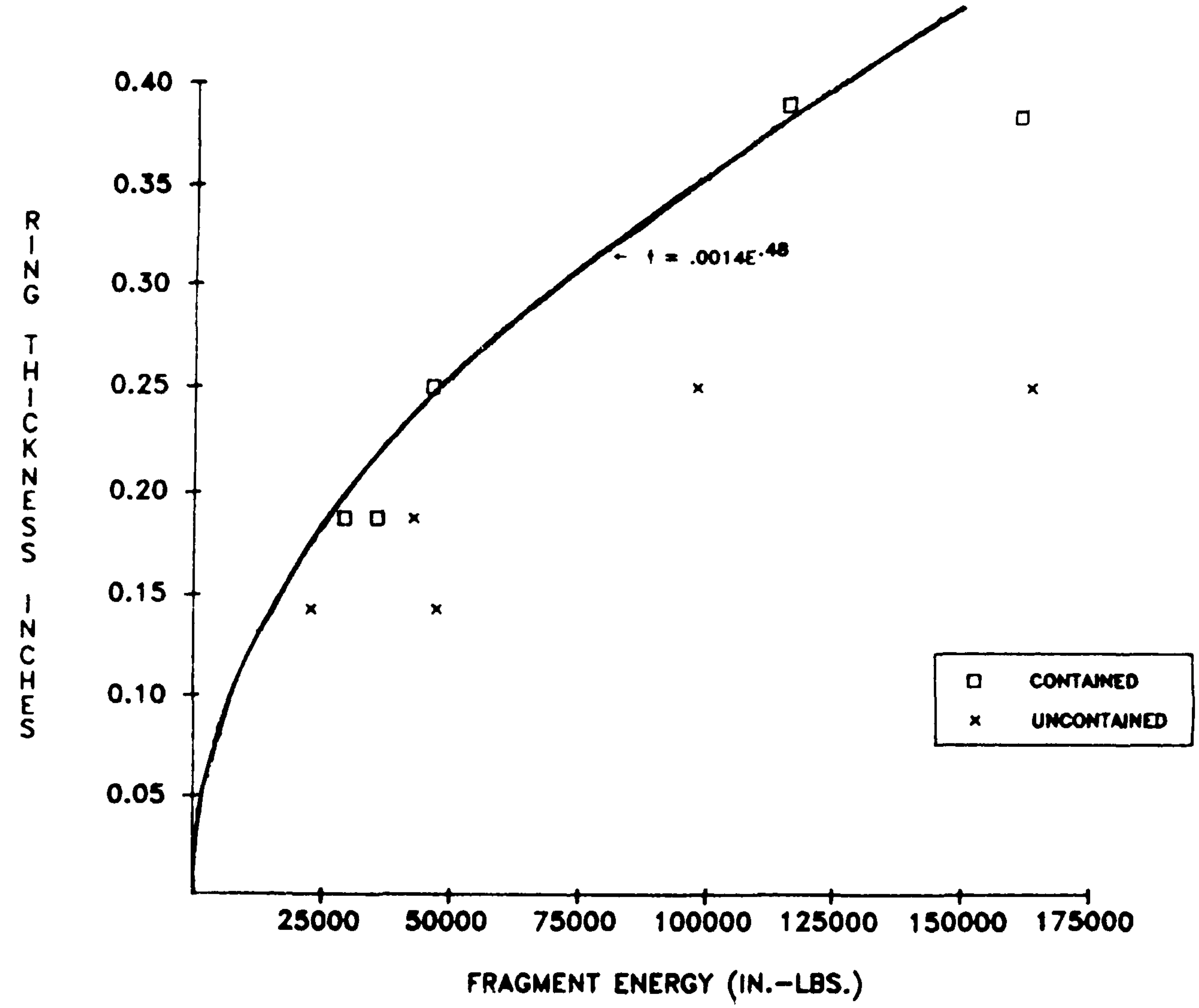


FIGURE 16. FRAGMENT ENERGY VERSUS CONTAINMENT RING THICKNESS

TABLE 1. ROTOR FRAGMENT CONTAINMENT EXPERIMENTS

TEST NO.	DATE	TYPE TEST	ROTOR/DISK TYPE	ROTOR/DISK MATERIAL	ROTOR/DISK DIAMETER INCHES	ROTOR/DISK NO. OF FRAGMENTS	ROTOR/DISK SPEED (RPM)	ROTOR/DISK ENERGY (IN-LBS)	CONTAINMENT/CONTROL CONFIGURATION	CONTAINMENT/CONTROL MATERIAL	CONTAINMENT/CONTROL ID INCHES	CONTAINMENT/CONTROL THICKNESS INCHES	CONTAINMENT/CONTROL AXIAL LENGTH INCHES	CONTAINMENT/CONTROL WEIGHT LBS	RESULTS
215	[illegible]/14/76	RB (1)	TURBINE ROTOR (3)	A-286	14.0	3	19855	851020	RING	KEVLAR (5)	15.0	UNDETERMINED	6.0	5.40	PARTIALLY CONTAINED
218	[illegible]/2/76	RB	TURBINE ROTOR (3)	A-286	14.0	3	20549	989709	RING	KEVLAR (5)	15.4375	UNDETERMINED	6.0	6.659	CONTAINED
219	10/19/76	RB	TURBINE ROTOR (3)	A-286	14.0	6	20805	995111	RING	KEVLAR (5)	15.375	UNDETERMINED	6.109	5.250	NOT CONTAINED
220	12/[illegible]/76	RB	TURBINE ROTOR (3)	A-286	14.0	3	19649	904913	RING	KEVLAR (5)	15.375	UNDETERMINED	6.125	4.75	PARTIALLY CONTAINED
221	2/16/77	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	8000	8726760	RING	KEVLAR (5)	32.4	.25	9.0	57.50	CONTAINED
222	4/2[illegible]/77	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	8222	9036194	RING	KEVLAR (5)	32.125	.275	12.0	71.47	CONTAINED
226	9/1/77	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	8000	8554816	RING	KEVLAR (5)	32.312	.22	11.0	55.5	NOT CONTAINED
229	11/7/77	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	7960	8469402	RING	KEVLAR (5)	32.375	.25	12.0	58.5	NOT CONTAINED
241	12/12/80	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	8200	8987904	RING	NYLON (7)	32.25	.25	12.5	65	NOT CONTAINED
243	1/30/91	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	7734	901353	RING	NYLON (7)	31.3125	.21875	12.5	65	NOT CONTAINED
244	2/2/81	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	8300	9 38900	RING	NYLON (7)	31.3125	.21875	12.5	66	NOT CONTAINED
245	2/4/81	RB	TURBINE ROTOR (4)	17-22A FERRITIC STEEL	30.640	3	7583	7678243	RING	KEVLAR (6)	31.3125	16.5 WRAPS	12.5	65	NOT CONTAINED

DATA COMPILATION FOOTNOTES FOR TABLES 1 AND 2:

(1) Rotor Burst. (2) Blade Burst.

(3) Turbine Rotor T58 Engine, Axial Flow Power Turbine Rotor Tip to Hub Ratio = 2.147, Blade Material: SEL, Rotor Material: A-286 (Figures 1 to 6).

(4) Turbine Rotor Curtiss-Wright J65 Second Stage, Axial Flow.
(5) Kevlar ring fabricated and wrapped by Boeing Company.
(6) Kevlar ring fabricated by Pioneer Parachute Company and wrapped by Navy.
(7) Nylon ring fabricated by Pioneer Parachute Company.

(8) Turbine Rotor Pratt & Whitney JT3D LPT-2, Axial Flow Turbine, Rotor Tip to Hub Ratio = 1.666, Blade Material: AMS 5382, Rotor Material: PWA 1003

(9) Turbine Rotor Pratt & Whitney JT8D LPT-1, Axial Flow Turbine, Rotor Tip to Hub Ratio = 1.458, Blade Material: AMS 5391 (INCONEL 713C), Rotor Material: AMS 5735 (A-286)

TABLE 2. BLADE CONTAINMENT EXPERIMENTS

TEST NO.	DATE	TYPE TEST	ROTOR/DISK TYPE	ROTOR/DISK MATERIAL	ROTOR/DISK DIAMETER INCHES	ROTOR/DISK NO. OF FRAGMENTS	ROTOR/DISK SPEED (RPM)	ROTOR/DISK ENERGY (IN-LBS)	CONTAINMENT/CONTROL CONFIG-URATION	CONTAINMENT/CONTROL MATERIAL	CONTAINMENT/CONTROL ID INCHES	CONTAINMENT/CONTROL THICKNESS INCHES	CONTAINMENT/CONTROL AXIAL LENGTH INCHES	CONTAINMENT/CONTROL WEIGHT LBS	RESULTS
• 236	4/15/80	88 (2)	JT3D LPT2 (8)	PWA 1003	34.9375	1	7152	50803	FLANGED RING	ALUMINUM	36	1/32	7	3	NOT APPLICABLE
• 237	[illegible]/2/80	88	JT3D LPT2	PWA 1003	34.9375	1	6450	41319	FLANGED RING	ALUMINUM	36	1/32	7	3	NOT APPLICABLE
• 238	7/2/80	88	JT3D LPT2	PWA 1003	34.9375	1	6000	35755	—	—	—	—	—	—	NOT APPLICABLE
• 239	[illegible]	88	JT3D LPT2	PWA 1003	34.9375	1	6300	39419	—	—	—	—	—	—	NOT APPLICABLE
• 240	10/1/80	88	JT3D LPT2	PWA 1003	34.9375	1	6492	41860	—	—	—	—	—	—	NOT APPLICABLE
• 242	1/12/81	88	JT3D LPT2	PWA 1003	34.9375	1	7169	49373	RING	304 STAINLESS STEEL	35.05	.390	9	112	NOT APPLICABLE
246	7/14/81	88	JT3D LPT2	PWA 1003	34.94	1	6145	36275	RING	A-286	35.05	.187	9	55	CONTAINED
248	[illegible]/9/81	88	JT3D LPT2	PWA 1003	34.94	1	7020	47337	RING	A-286	35.05	.140	9	39	NOT CONTAINED
249	10/9/81	88	JT3D LPT2	PWA 1003	34.9375	1	6736	43580	RING	A-286	35.05	.187	9	54	NOT CONTAINED
250	10/21/81	88	JT3D LPT2	PWA 1003	34.9375	1	6942	46295	RING	A-286	35.05	.250	9	70	CONTAINED
• 251	12/11/81	88	JT3D LPT-2	PWA 1003	34.9375	3	7245	174900	RING	304 STAINLESS STEEL	35.05	.390	99	112	NOT APPLICABLE
• 252	7/27/82	88	JT8D LPT-1 (9)	A-286	27.35	1	•7600	19739	RING	304 STAINLESS STEEL	28	393	9	56.54	NOT APPLICABLE
• 253	[illegible]/26/82	88	JT8D LPT-1	A-286	27.35	1	9900	33494	RING	304 STAINLESS STEEL	28	393	9	56.54	NOT APPLICABLE
• 254	[illegible]/19/82	88	JT8D LPT-1	A-286	27.35	1	9024	27830	RING	304 STAINLESS STEEL	28	393	9	56.54	NOT APPLICABLE
256	11/[illegible]/82	88	JT8D LPT-1	A-286	27.35	1	9360	29916	RING	A-286	28	187	9	40	CONTAINED
257	2/10/83	88	JT8D LPT-1	A-286	27.35	1	8290	23406	RING	A-286	28	140	9	32.5	NOT CONTAINED
258	4/7/83	88	JT8D LPT-1	A-286	27.35	3	8200	98945	RING	A-286	28	.250	9	55	NOT CONTAINED
259	7/1/83	88	JT8D LPT-1	A-286	27.35	3	8888	116219	RING	A-286	28	.390	9	89.5	CONTAINED
260	12/14/83	88	JT3D LPT-2	PWA 1003	34.9375	3	6907	163479	RING	A-286	35.05	244	9	69.5	NOT CONTAINED
261	5/20/84	88	JT3D LPT-2	PWA 1003	34.9375	3	6805	161250	RING	A-286	35.05	304	9	110.5	CONTAINED

• Indicates preliminary test

REFERENCES

1. Salvino, J. T. and DeLucia, R. A., Rotor Fragment Protection Program: Experimentation to Provide Guidelines for the Design of Turbine Rotor Fragment Containment Rings, Report No. NAPC-PE-33, Naval Air Propulsion Center, Trenton, NJ, January 1980.

2. Mangano, G. J., Salvino, J. T. and DeLucia, R. A., Rotor Burst Protection Program: Experimentation to Provide Guidelines for the Design of Turbine Rotor Burst Fragment Containment Rings, Report No. NAPTC-PE-98, Naval Air Propulsion Test Center, Trenton, NJ, March 1977.

3. Mangano, G. J., Rotor Burst Protection Program - Phases VI and VII; Exploratory Experimentation to Provide Data for the Design of Rotor Burst Fragment Containment Rings, Report No. NAPTC-AED-1968, Naval Air Propulsion Test Center, Trenton, NJ, March 1972.

4. Martino, A. A. and Mangano, G. J., Rotor Burst Protection Program - Final Phase V Report on Problem Assignment NASA DPR R-105, Report No. NAPTC-AED-1901, Naval Air Propulsion Test Center, Trenton, NJ, May 1969.

5. Martino, A. A. and Mangano, G. J., Rotor Burst Protection Program - Final Phase IV Report on Problem Assignment NASA DPR R-105, Report No. NAPTC-AED-1869, Naval Air Propulsion Test Center, April 1968.

6. Martino, A. A. and Mangano, G. J., Turbine Disk Burst Protection Study, Final Phase II-III Report on Problem Assignment NASA DPR R-105, Report No. NAPTC-AEL-1848, Naval Air Propulsion Test Center, Trenton, NJ, February 1967.

7. Martino, A. A., Turbine Disk Burst Protection Study - Final Phase I Report on Problem Assignment NASA DPR R-105, Report No. NAEC-AEL-1793, Naval Air Propulsion test Center, Trenton, NJ, March 1965.

APPENDIX A

CLOTH CONTAINMENT RINGS MANUFACTURING TECHNIQUE

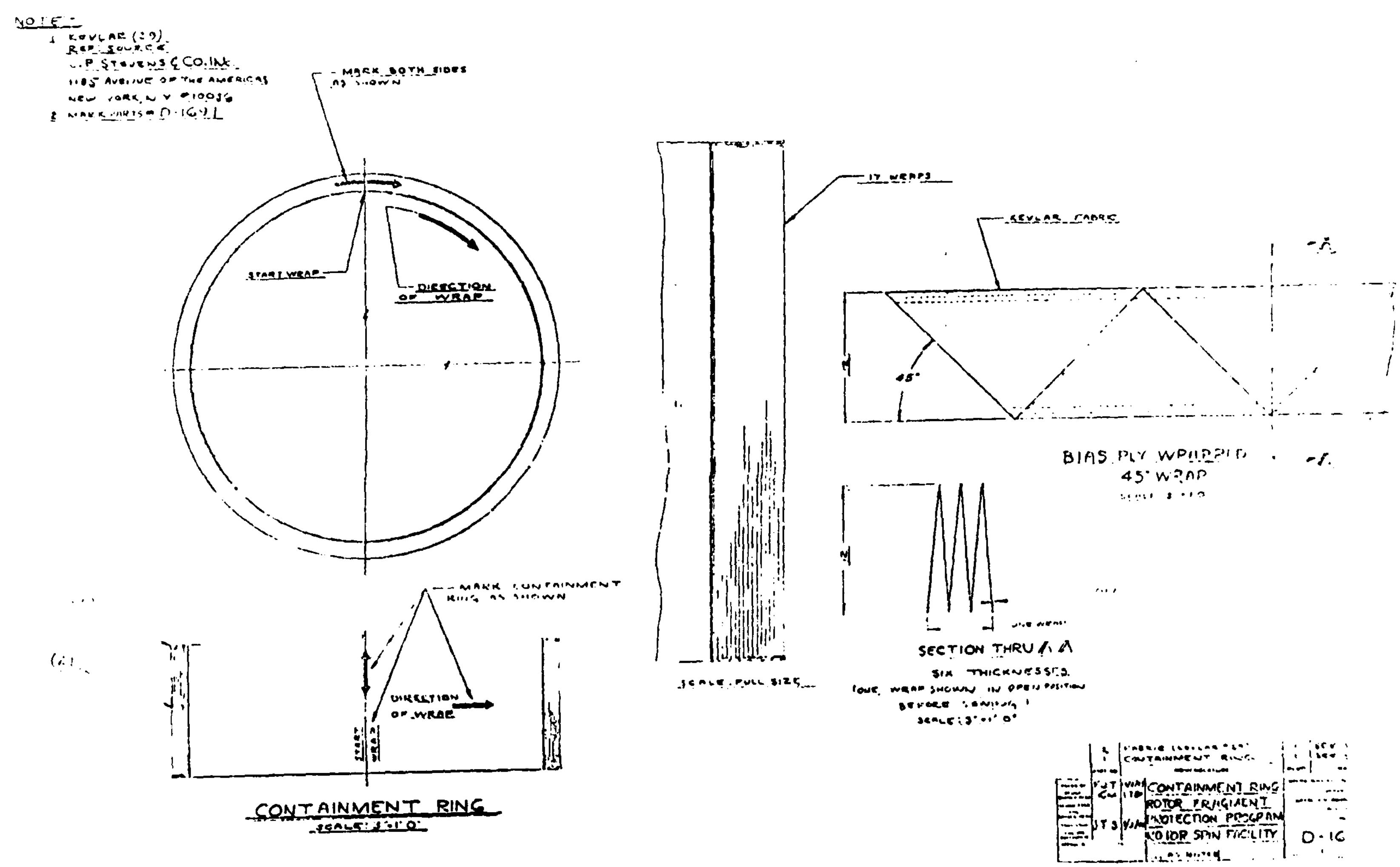


FIGURE A-1. KEVLAR CONTAINMENT RING MANUFACTURING DRAWING (1 OF 3)

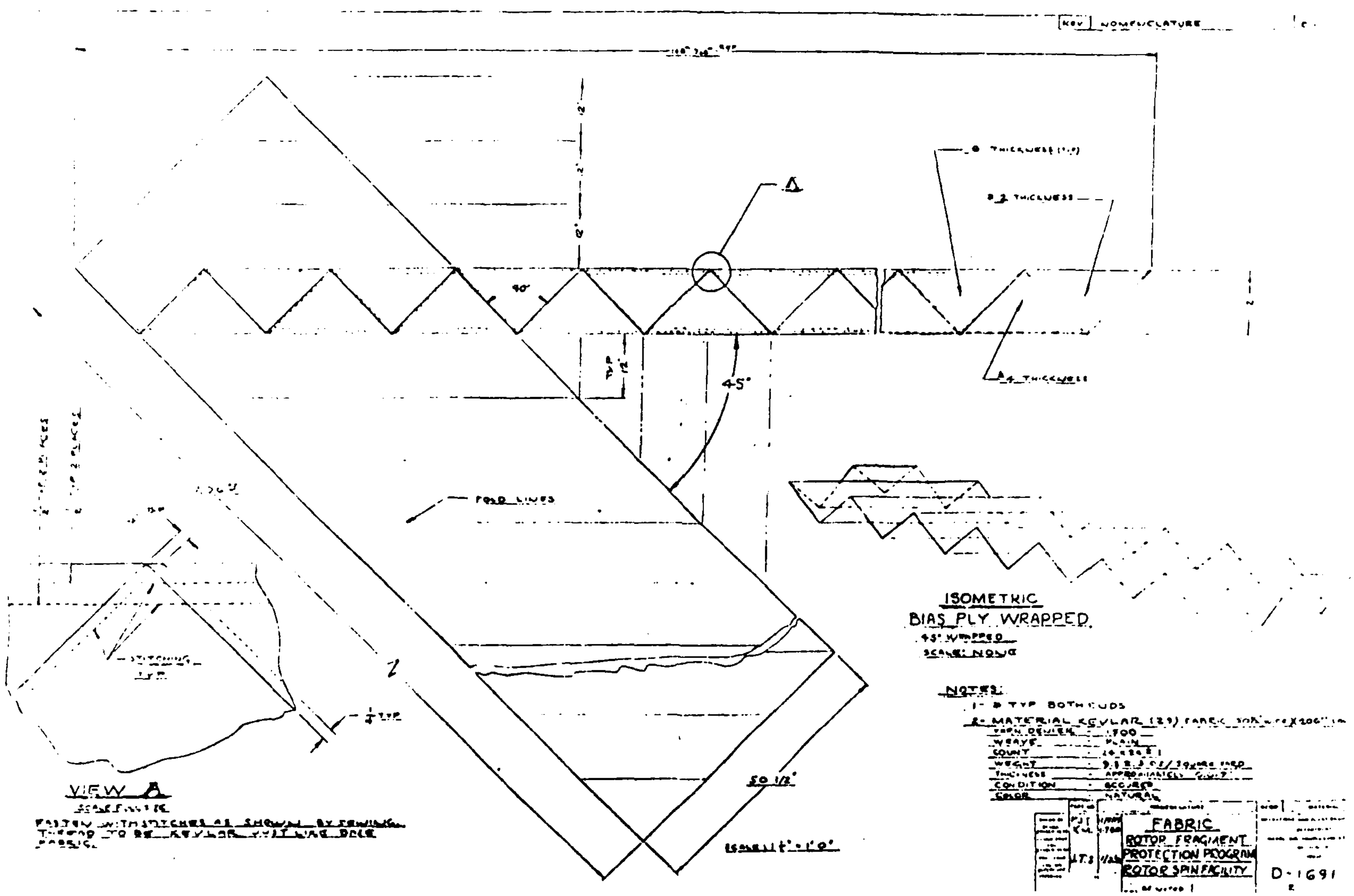


FIGURE A-2. KEVLAR CONTAINMENT RING MANUFACTURING DRAWING (2 OF 3)

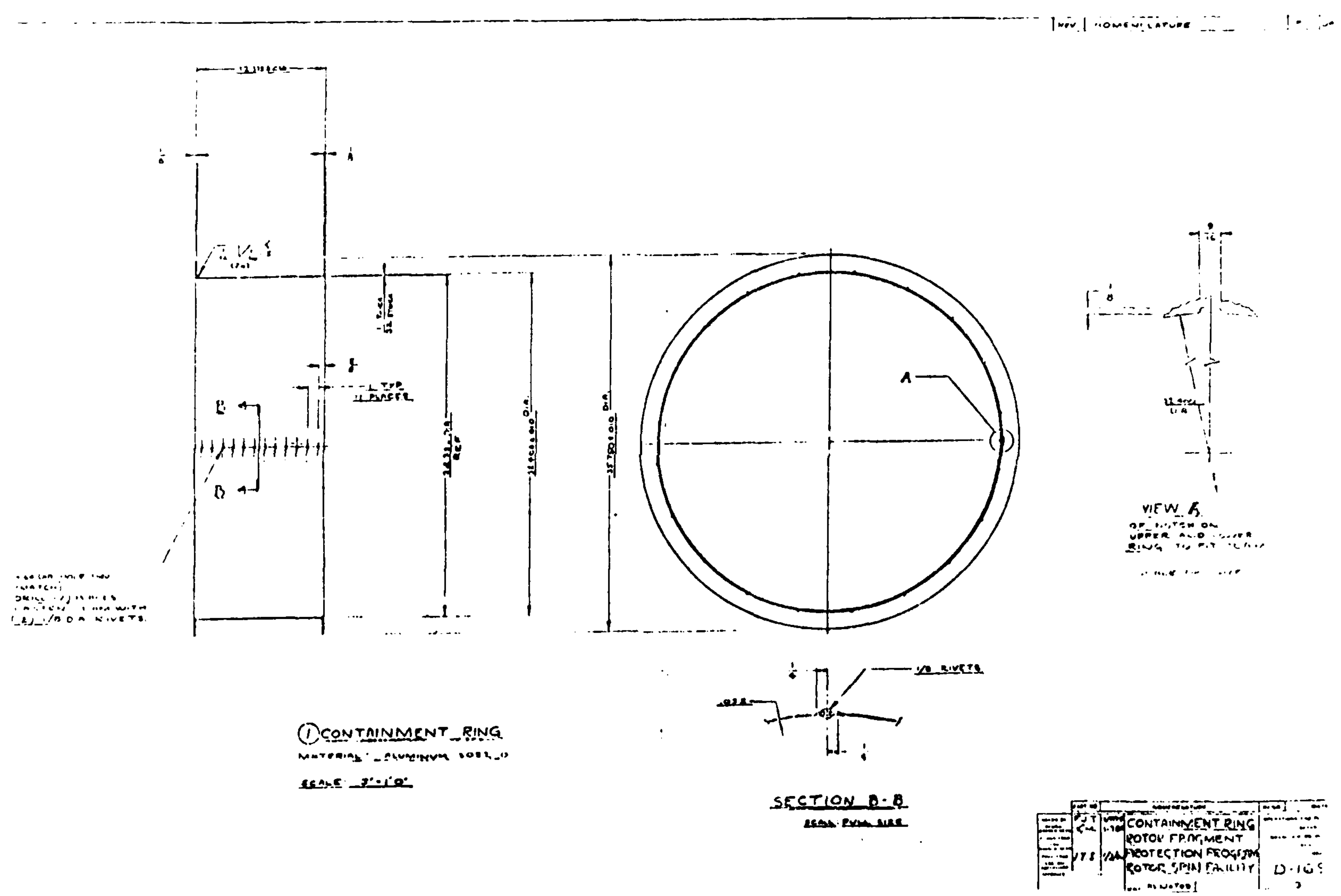


FIGURE A-3. KEVLAR CONTAINMENT RING MANUFACTURING DRAWING (3 OF 3)

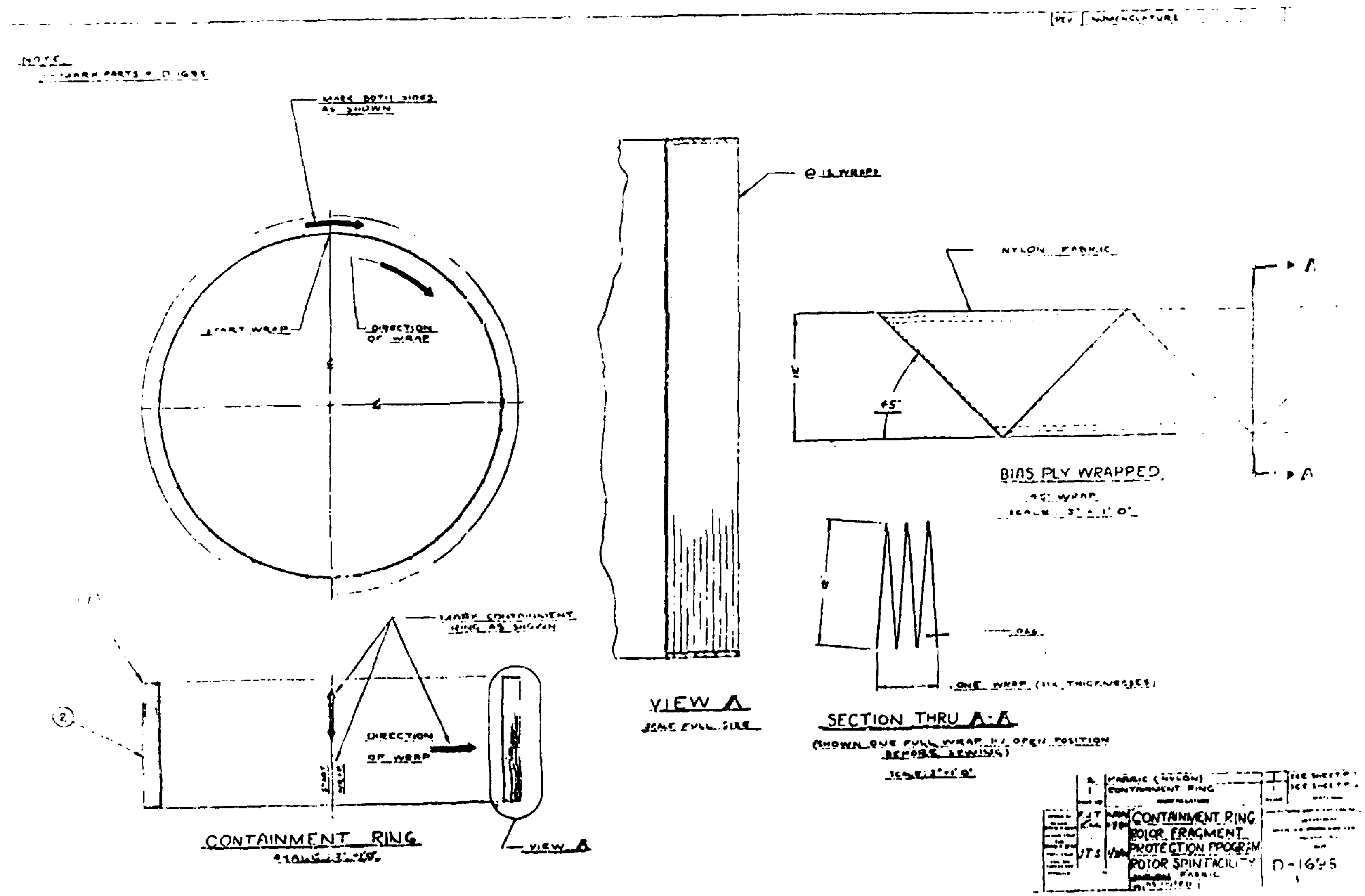


FIGURE A-4. NYLON CONTAINMENT RING MANUFACTURING DRAWING (1 OF 3)

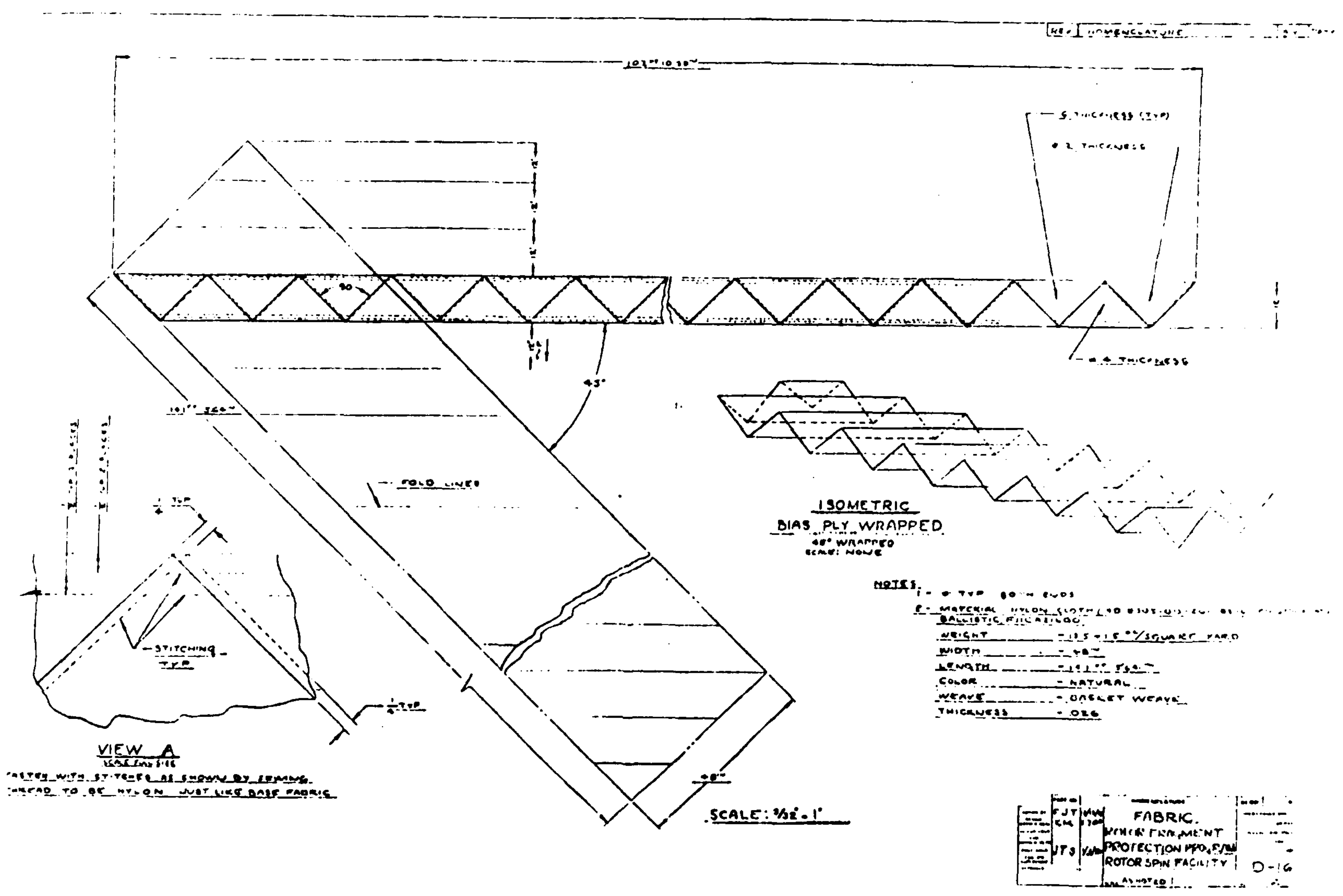


FIGURE A-5. NYLON CONTAINMENT RING MANUFACTURING DRAWING (2 OF 3)

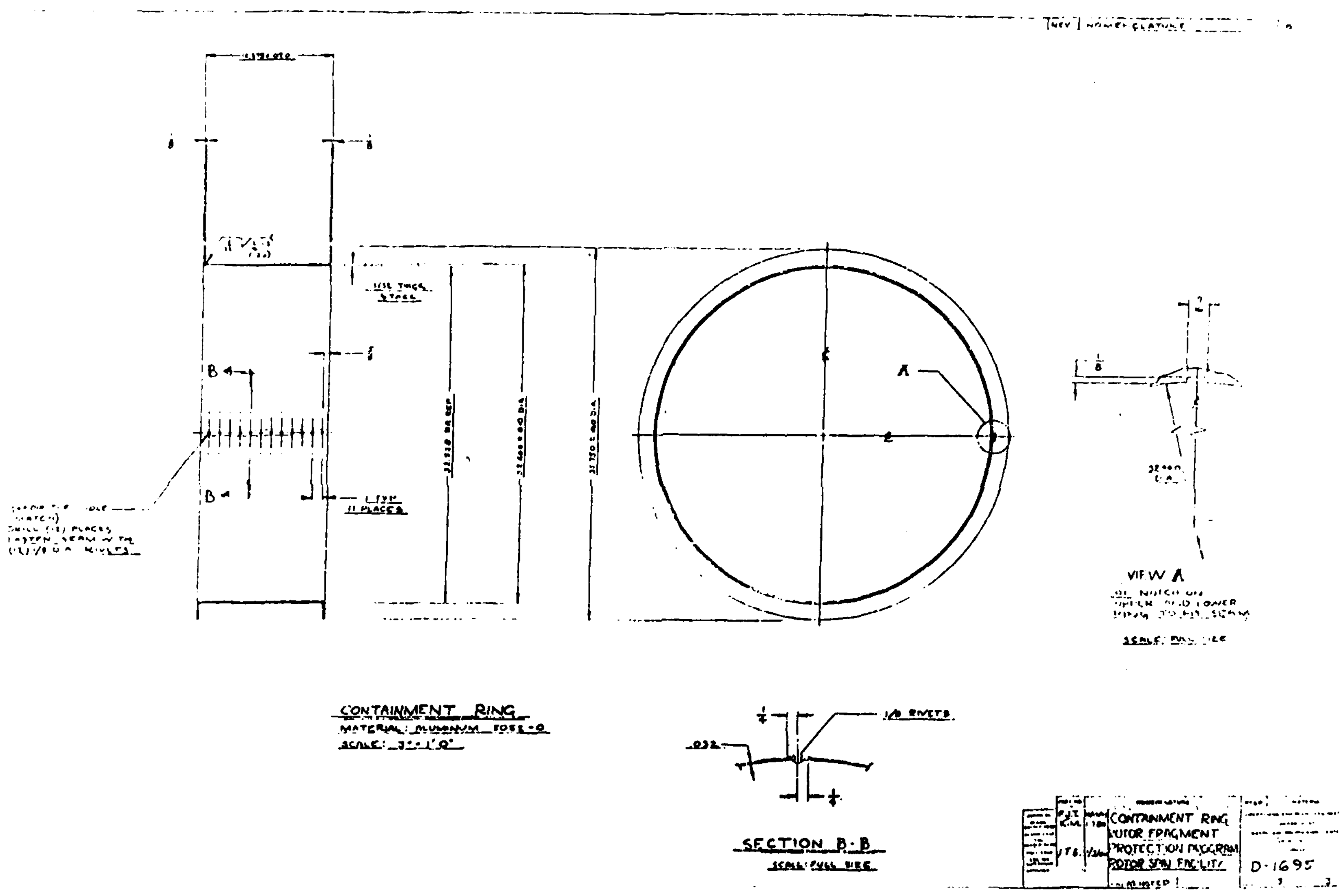


FIGURE A-6. NYLON CONTAINMENT RING MANUFACTURING DRAWING (3 OF 3)

APPENDIX B

DISTRIBUTION LIST

Civil Aviation Authority (5)
Aviation House
129 Kingsway
London WC2B 6NN
ENGLAND

DOT/FAA Eastern Region (3)
AEA-61
JFK International Airport
Fitzgerald Federal Building
Jamaica, NY 11430

Embassy of Australia
Civil Air Attache
1601 Massachusetts Avenue, NW.
Washington, DC 20036

DOT/FAA National Headquarters
ADL-32
800 Independence Avenue, SW.
Washington, DC 20591

Scientific and Technical Information FAC
ATTN: NASA Representative
P.O. Box 8757 BWI Airport
Baltimore, MD 21240

DOT/FAA National Headquarters
AES-3
800 Independence Avenue, SW.
Washington, DC 20591

Northwestern University
Trisnet Repository
Transporation Center Library
Evanston, IL 60201

DOT/FAA Northwest Mountain Region (2)
ANM-60
17900 Pacific Highway South
C-68966
Seattle, WA 98168

DOT/Federal Aviation Administration (5)
AEU-500
American Embassy
APO New York, NY 09667

DOT/FAA Technical Center (2)
Technical Library, ACT-65A
Atlantic City Int'l Airport, NJ 08405

University of California
Service Department Institute of
Transportaion Standard Lab
412 McLaughlin Hall
Berkeley, CA 94720

DOT/FAA Alaskan Region (2)
AAL-400
701 C Street, Box 14
Anchorage, AK 99513

British Embassy
Civil Air Attache ATS
3100 Massachusetts Avenue, NW.
Washington, DC 20008

Department of Transportation (5)
Office of the Secretary
M-493.2, Building 10A
400 7th Street, SW.
Washington, DC 20590

DOT/FAA Southern Region (2)
ASO-52C4
P.O. Box 20636
Atlanta, GA 30320

DOT/FAA National Headquarters
APM-1
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters (2)
APS-13, Nigro
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
APA-300
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA Great Lakes Region (2)
AGL-60
O'Hare Office Center
2300 East Devon Avenue
Des Plaines, IL 60018

DOT/FAA Southwest Region (2)
ASW-53B
P.O. Box 1689
Fort Worth, TX 76101

DOT/FAA Mike Monroney Aeronautical Center (2)
AAC-64D
P.O. Box 25082
Oklahoma City, OK 73125

DOT/FAA Central Region (2)
ACE-66
601 East 12th Street
Federal Building
Kansas City, MO 64106

DOT/FAA National Headquarters
ADL-1
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
ALG-300
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA Technical Center
Public Affairs Staff, ACT-5
Atlantic City Int'l Airport, NJ 08405

DOT/FAA National Headquarters
ASF-1
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
ASF-100
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
ASF-200
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
ASF-300
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
AST-1
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
ADL-2A
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters (4)
AVS-1, 100, 200, 300
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
AFS-1
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
AFS-200
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
AWS-1
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
AWS-100
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
AWS-120
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
APO-1
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA National Headquarters
APO-200
800 Independence Avenue, SW.
Washington, DC 20591

DOT/FAA Great Lakes Region
Mr. R. Prather, ACE-140C
O'Hare Office Center
2300 East Devon Avenue
Des Plaines, IL 60018

DOT/FAA Great Lakes Region
ACE-140
O'Hare Office Center
2300 East Devon Avenue
Des Plaines, IL 60018

DOT/FAA Great Lakes Region
AGL-200
O'Hare Office Center
2300 East Devon Avenue
Des Plaines, IL 60018

DOT/FAA Central Region
ACE-100
601 East 12th Street
Federal Building
Kansas City, MO 64106

DOT/FAA Central Region
Mr. Oscar Ball, ACE-100
601 East 12th Street
Federal Building
Kansas City, MO 64106

DOT/FAA Central Region
ACE-200
601 East 12th Street
Federal Building
Kansas City, MO 64106

DOT/FAA Eastern Region
AEA-200
JFK International Airport
Fitzgerald Federal Building
Jamaica, NY 11430

DOT/FAA New England Region
ANE-100
12 New England Executive Park
Burlington, MA 01803

DOT/FAA New England Region
ANE-110
12 New England Executive Park
Burlington, MA 01803

DOT/FAA New England Region
ANE-140
12 New England Executive Park
Burlington, MA 01803

DOT/FAA New England Region
ANE-141
12 New England Executive Park
Burlington, MA 01803

DOT/FAA New England Region
ANE-142
12 New England Executive Park
Burlington, MA 01803

DOT/FAA Northwest Mountain Region
ANM-100
17900 Pacific Highway South
C-68966
Seattle, WA 98168

DOT/FAA Northwest Mountain Region
ANM-110
17900 Pacific Highway South
C-68966
Seattle, WA 98168

DOT/FAA Northwest Mountain Region
ANM-200
17900 Pacific Highway South
C-68966
Seattle, WA 98168

DOT/FAA Southern Region
ASO-200
P.O. Box 20636
Atlanta, GA 30320

DOT/FAA Southwest Region
ASW-100
P.O. Box 1689
Fort Worth, TX 76101

DOT/FAA Southwest Region
ASW-110
P.O. Box 1689
Fort Worth, TX 76101

DOT/FAA Southwest Region
M. Mathias, ASW-111
P.O. Box 1689
Fort Worth, TX 76101

DOT/FAA Southwest Region
ASW-200
P.O. Box 1689
Fort Worth, TX 76101

Federal Aviation Administration
Chief, Civil Aviation Assistance Group
Madrid, Spain
c/o American Embassy
APO New York 09285-0001

Mr. A. R. Tobiason
ATA of America
1709 New York Avenue, NW.
Washington, DC 20006

Federal Aviation Administration
Anchorage ACO
701 C Street, Box 14
Anchorage, AK 99513

Federal Aviation Administration
Atlanta ACO
1075 Inner Loop Road
College Park, GA 30337

Federal Aviation Administration
Boston ACO
12 New England Executive Park
Burlington, MA 01803

Federal Aviation Administration
Brussels ACO
c/o American Embassy
APO
New York, NY 09667

Federal Aviation Administration
Chicago ACO
Room 232
2300 East Devon Avenue
Des Plaines, IL 60018

Federal Aviation Administration
Denver ACO
10455 East 25th Avenue
Suite 307
Aurora, CO 98168

Mr. Frank Taylor
3542 Church Road
Ellicott City, MD 21043

Federal Aviation Administration
Mr. Al Astorga, CAAG
American Embassy
Box 38
APO New York 09285-0001

DOT Transportation Safety Institute
Mr. Burton Chesterfield, DMA-603
6500 South MacArthur Boulevard
Oklahoma City, OK 73125

Federal Aviation Administration
Fort Worth ACO
P.O. Box 1689
Fort Worth, TX 76101

Federal Aviation Administration
Long Beach ACO
ANM-140L
4344 Donald Douglas Drive
Long Beach, CA 90808

Federal Aviation Administration
Los Angeles ACO
P.O. Box 92007
Worldway Postal Center
Hawthorne, CA 90009

Federal Aviation Administration
New York ACO
Room 202
181 South Franklin Avenue
Valley Stream, NY 11581

Federal Aviation Administration
Seattle ACO
17900 Pacific Highway South
C-68966
Seattle, WA 98168

Federal Aviation Administration
Wichita ACO, Mid Continent Airport
FAA Building, Room 100
1891 Airport Road
Wichita, KS 67209

Mr. A. Allcock
Department of Industry
Abell House, Room 643
John Islip Street, London, SW14 LN
ENGLAND

Dr. S. J. Armour
Defense Research Establishment
Suffield
Ralston, Alberta
CANADA, TOJ 2NO

Captain Ralph Cantrell
University of Bridgeport
U.S. Army ROTC Department
Bridgeport, CT 06601

Mr. George A. Coffinberry
General Electric Company
1 Neumann Way
Mail Drop E-186
Cincinnati, OH 45215

Mr. J. Donald Collier
Air Transport Association
of America
1709 New York Avenue, NW.
Washington, DC 20006

Captain Ralph Combariati
Port Authority of NY and NJ
JFK International Airport
Jamaica, NY 11430

Mr. Edward Conklin
Sikorsky Aircraft
North Main Street
Stratford, CT 06602

Mr. Dick Coykendall
United Airlines
San Francisco International
Airport
San Francisco, CA 94128

Mr. David M. Blake
General Electric Company
Aircraft Engine Field Operations
1515 Market Street
Philadelphia, PA 19102

Mr. Terence Dixon
Boeing Aerospace Corporation
P.O. Box 3999
M/S 8J-93
Seattle, WA 98124

Mr. Thomas F. Donohue
General Electric Company
1 Neumann Way, Mail Drop H-44
P.O. Box 156301
Cincinnati, OH 45215-6301

Mr. John H. Enders
Flight Safety Foundation
5510 Columbia Pike
Arlington, VA 22204

Dr. Allen E. Fuhs
Department of Aeronautics
Naval Post Graduate School
Monterey, CA 93940

Y. Funatsu
All Nippon Airways
1-6-6, Tokyo International Airport
Ohta-KU, Tokyo 144
JAPAN

Henry A. Gill
Lockheed California Company
Building 88, B-6
P.O. Box 551
Burbank, CA 91520

Mr. David J. Goldsmith
Eastern Airlines
Miami International Airport
Miami, FL 33148

Mr. Stanley Gray
Mechanical Technology Inc.
968 Albany Shaker Road
Latham, NY 12110

G. Haigh
Air Canada
Air Canada Base, Montreal
International Airport
Quebec, CANADA H4Y 1 C2

M. Hardy
United Airlines
SFOEG, MOC
San Francisco International Airport
California 94128

W. Hock
Grumman Aerospace Corporation
B 14 035
111 Stewart Avenue
Bethpage, NY 11714

LCDR William Holland
Department of the Navy
NAVAIR 518
Naval Air Systems Command
Washington, DC 20361

Major Hudson
Air Force Inspection and Safety
SEDM
Norton Air Force Base, CA 92499

Mr. J. P. Jamieson
National Gas Turbine Establishment
Pyestock, Farnborough
Hants GU14 OLS
ENGLAND

Dr. C. W. Kauffman
The University of Michigan
Gas Dynamics Laboratories
Aerospace Engineering Building
Ann Arbor, MI 48109

FAA National Headquarters
Mr. H. Branting, AWS-120
800 Independence Avenue, SW.
Washington, DC 20591

Mr. Richard J. Linn
American Airlines
MD 4H14
P.O. Box 61616
Dallas/Fort Worth Airport, TX 75261

Captain A. S. Mattox, Jr.
Allied Pilots Association
12723 Brewster Circle
Woodbridge, VA 22191

Mr. Charles McGuire
Department of Transportation
400 7th Street, SW. (P-5)
Washington, DC 20590

Harold Marthinsen
Airline Pilots Association
Accident Investigation Department
P.O. Box 1169
Herndon, VA 22070

Dean Oliva
Lockheed
Department 7475/Building 229A
P.O. Box 551, Plant 2
Burbank, CA 91520

Dr. Robert C. Oliver
Institute for Defense Analyses
1801 North Bauregard Street
Alexandria, VA 22311

Mr. George Opdyke
AVCO Lycoming Division
550 South Main Street
Stratford, CT 06497

Dr. Robert H. Page
Texas A&M University
College of Engineering
College Station, TX 77884

Mr. Roy E. Pardue
Lockheed/Georgia Company
86 South Cubb Drive
Marietta, GA 30063

Mr. Tom Peacock
Douglas Aircraft Company
3855 Lakewood Boulevard
Longbeach, CA 90846

Mr. William Rodenbaugh
General Electric Company
Manager, Operational Planning
1000 Western Avenue
Lynn, MA 01910

C. C. Randall, P.E.
Lockheed Georgia Company
D72-47 Zone 418
Marietta, GA 30063

M. Rippen
Pratt and Whitney Aircraft
Government Products Division
P.O. Box 2691
West Palm Beach, FL 33402

E. T. Roockey
Northrop Corporation
Aircraft Division
One Northrop Avenue
Hawthorne, CA 90250

Professor Valentinas Sernas
Rutgers University
College of Engineering
P.O. Box 909
Piscataway, NJ 08854

S. Sokolsky
Aerospace Corporation
P.O. Box 91957
Los Angeles, CA 90009

Dr. Warren C. Strahle
Georgia Institute of Technology
School of Aerospace Engineering
Atlanta, GA 30332

Mr. Dick Stutz
Sikorsky Aircraft
Engineering Department
Stratford, CT 06602

Mr. A. F. Taylor
Cranfield Institute of Technology
Cranfield, Bedford, MK 43 OAL
ENGLAND

Mr. Fred Grenich
Boeing Military Airplane Company
P.O. Box 3707
M/S 4152
Seattle, WA 98124

M. Trimble
Delta Airlines
DEAT 568
Atlanta International Airport
Atlanta, GA 30320

Mr. T. Ted Tsue
Boeing Aerospace Company
P.O. Box 3999
M/S 45-07
Seattle, WA 98124

Trans World Airlines, Inc.
Kansas City International Airport
2-280
P.O. Box 20126
Kansas City, MO 64195

Mr. Ed Versaw
Lockheed/California Company
P.O. Box 551
Burbank, CA 91520

Mr. John White
National Transportation
Safety Board
800 Independence Avenue, SW.
Washington, DC 20594

Dr. S. P. Wilford
Royal Aircraft Establishment
Farnborough, Hants
GU146TD
ENGLAND

R. E. Zalesky
Lockheed California Company
P.O. Box 551
Burbank, CA 91520

Dr. Robert F. Abernethy
Pratt and Whitney Government Products
MS 711-33
Box 2691
West Palm Beach, FL 33408

Mr. James N. Bagnall
Hamilton Standard Division
United Technologies Corporation
Bradley Field Road, M/S 1A-3-6
Windsor Locks, CT 06096

Mr. Vern W. Ballenger
Director of Engineering
Air Transport Association
1709 New York Avenue, NW.
Washington, DC 20006

H. R. Bankhead
Department of the Air Force
AFWAL/POTP
Wright-Patterson Air Force Base
Dayton, OH 45433-6563

J. A. DeMarche
Commercial Products Division
UTC Pratt and Whitney Aircraft
Engineering Building 163-12
East Hartford, CT 06108

Mr. Rudy Schwartz
Rolls-Royce Inc.
1201 Pennsylvania Avenue
Suite 230
Washington, DC 20004

Mr. Robert L. Ivan
Chief, Propulsion Division, ASD ENFP
Department of the Air Force
Wright-Patterson Air Force Base
Dayton, OH 45433

Mr. Michael D. Mead
Senior Engineer
Naval Air Systems Command
AIR 5360D
Washington, DC 20361

E. W. Walacavage, AIA Propulsion Comm.
Garrett Turbine Engine Company
111 South 34th Street
P.O. Box 5217
Phoenix, AZ 85010

J. P. Frignac, MS 503-3B
Garrett Turbine Engine Company
111 South 34th Street
P.O. Box 5217
Phoenix, AZ 85010

Mr. Daniel R. Gerard
Flight Support Directorate
Airbus Industries, Headquarters BP #33
Blagnac
FRANCE 31700

Mr. Allen E. Heyson
Aircraft Engine Group
General Electric Company
Mail Drop E-65
Cincinnati, OH 45215

Mahlon R. Hoover
Manager, Prop & Mech Syst, M/S 6F-25
Boeing Commercial Airplane Company
P.O. Box 3707
Seattle, WA 98124

Mr. George Bianchini
Allison Gas Turbine Division
General Motors Corporation
P.O. Box 420
Indianapolis, IN 46206-0420

Mr. Harry L. Lemasters
Structures Technology, MS 163-09
Pratt and Whitney Aircraft
400 Main Street
East Hartford, CT 06108

Mr. J. Fresco
Societe Turbomeca
Siege Social, Bureaux et Usine
Bordes, Bizanos
FRANCE 64320

Mr. Ronald G. Jackson
Product Support
Rolls-Royce, Inc.
1895 Phoenix Boulevard
Altanta, GA 30349

Mr. Kenneth M. Johnson, Jr.
Williamsport Division
Avco Lycoming
652 Oliver Street
Williamsport, PA 17701

Mr. Alan J. Lea, 01MD4
Pratt and Whitney Canada, Inc.
P.O. Box 10
Longueuil, Quebec J4K4X9
CANADA

Mr. Martyn Hexter
Pratt and Whitney Canada, Inc.
90 Dundas Street West
Mississauga, Ontario L5A 3Q4
CANADA

Mr. Richard Ainsworth
Stratford Division
Avco Lycoming
550 South Main Street
Stratford, CT 06497

Mr. John T. Moehring
General Electric Company
Flight Safety Section, Mail Drop J60
One Neuman Way
Cincinnati, OH 45215

Mr. Glenn Pittard
Garrett Turbine Engine Company
111 South 34th Street
P.O. Box 5217
Phoenix, AZ 85010

Mr. A. B. Wassell
Rolls-Royce Ltd.
P.O. Box 31
Derby DE2 8BJ
ENGLAND

Mr. T. Dickey
Stratford Division
Avco Lycoming
550 South Main Street
Stratford, CT 06497

Dr. John R. Fagan, M.S. T15
Allison Gas Turbine Division
General Motors Corporation
P.O. Box 420
Indianapolis, IN 46210-0420

Mr. Brad Stumpke
Mail Drop 34511
General Electric Company
1000 Western Avenue
Lynn, MA 01910

Mr. Richard Barnard
Sikorsky Aircraft Division
United Technologies Corporation
North Main Street
Stratford, CT 06602

Mr. Chet Lewis
Boeing Commerical Airplane Company
Mail Stop 9W-61
P.O. Box 3707
Seattle, WA 98124

Mr. Frank M. Shallene
Bell Helicopter Textron
P.O. Box 482
Fort Worth, TX 76101

Mr. Peter Dahm
Helicopter and Transport Division
Messerschmitt-Bolkon-Blohm GMBH
P.O. Box 801140 DX2, 8000 Munich 80
FEDERAL REPUBLIC OF GERNAMY

Mr. James B. Harbison
Boeing Vertol Company
MS 32-17
P.O. Box 16858
Philadelphia, PA 19142

Mr. Richard H. Johnson
Department E80, MC 36-41
Douglas Aircraft
3855 Lakewood Boulevard
Long Beach, CA 90846

Mr. John M. Kowalonek
Sikorsky Aircraft Division
United Technologies Corporation
North Main Street
Stratford, CT 06602

Dr. Kenneth M. Rosen
Sikorsky Aircraft Division
United Technologies Corporation
North Main Street
Stratford, CT 06601

Mr. Emmett A. Witmer
Aassachusetts Institute
of Technology
Cambridge, MA 02139

Mr. P. B. Gardner
Industrial Ceramics Division
Norton Company
One New Bond Street
Worcester, MA 01606

Mr. Jack A. Mitteer
Product Support
McDonnell Douglas Helicopter Company
5000 East McDowell Road
Mesa, AZ 85205

Captain Edwin R. Arbon
Flight Operations Safety
Flight Safety Foundation, Inc.
5510 Columbia Pike
Arlington, VA 22204-3194

Mr. Donald F. Thielke
Vice President, Safety Engineering
Flight Engineers' International Assoc.
905 16th Street, NW.
Washington, DC 20006

Mr. Barry Scott
P.O. Box 25
Moffett Field, CA 94035

Mr. A. T. Weaver, M.S. 165-30
Pratt and Whitney Aircraft
Airworthiness Engineering Division
400 Main Street
East Hartford, CT 06108

Mr. Steve Clark
Rolls-Royce Inc.
1895 Phoenix Boulevard
Atlanta, GA 30349

Mr. William Burcham
Propulsion Branch, Code OFV
NASA Ames - Dryden
P.O. Box 273
Edwards, CA 93523

Mr. Ralph E. Kesler
Delta Air Lines, Inc.
Hartsfield Atlanta International
Airport
Atlanta, GA 30320

Commander
Naval Air Systems Command
AIR-330
Department of the Navy
Washington, DC 20361

Commander
Naval Air Systems Command
AIR-330A
Department of the Navy
Washington, DC 20361

Commander
Naval Air Systems Command
AIR-5017A
Department of the Navy
Washington, DC 20361

Commander
Naval Air Systems Command
AIR-536
Department of the Navy
Washington, DC 20361

Commander
Naval Air Systems Command
AIR-5360
Department of the Navy
Washington, DC 20361

Commander
Naval Air Systems Command
AIR-5361
Department of the Navy
Washington, DC 20361

Commander
Naval Air Systems Command
AIR-5362
Department of the Navy
Washington, DC 20361

Commander
Naval Air Systems Command
AIR-530
Department of the Navy
Washington, DC 20361

Commanding Officer (15)
Naval Air Propulsion Center
PE32
P.O. Box 7176
Trenton, NJ 08628

Commanding Officer
Naval Air Engineering Center
Lakehurst, NJ 08733

Commanding Officer
Naval Air Development Center
Warminster, PA 18974

Commander
Naval Safety Center
Naval Air Station
Norfolk, VA 23511

Director
Applied Technology Laboratory
Army Research and Technology
Laboratories
Fort Eustis, VA 23604

Commanding General
U.S. Army Aviation Systems Command
AMSAV-ERP
12th and Spruce Streets
St. Louis, MO 63166

Commander
Air Force Aero Propulsion Laboratory
AFSC
Wright-Patterson Air Force Base
Dayton, OH 45433

Defense Technical Information Center
Building Number 5
Cameron Station
Alexandria, VA 22314

National Aeronautics and Space
Administration
NHS-22/Library
Washington, DC 20546

NASA S&T Information Facility
ATTN: Acquisition Division
P.O. Box 8757
Washington Internat'l Airport, MD 21240

NASA Lewis Research Center
Technology Utilization Office
21000 Brookpark Road
Cleveland, OH 44135

NASA Lewis Research Center
AFSC Liaison Office
21000 Brookpark Road
Cleveland, OH 44135

NASA Lewis Research Center
Library
21000 Brookpark Road
Cleveland, OH 44135

NASA Lewis Research Center
C. C. Chanis
21000 Brookpark Road
Cleveland, OH 44135

NASA Lewis Research Center
R. H. Johns
21000 Brookpark Road
Cleveland, OH 44135

United Airlines, Inc.
ATTN: J. D. Smith
VP, Flight Safety and Industry Affairs
P.O. Box 66100
Chicago, IL 60666

Pratt and Whitney Aircraft
Division of United Technologies Corp.
ATTN: Technical Library
400 Main Street
East Hartford, CT 06108

Canadian Air Transportation Admin.
ATTN: D. R. Hemming
No. 3 Temp. Building
Wellington Street, Ottawa, Ontario
CANADA

Rolls-Royce Limited
ATTN: S. Cox, Bristol Engine Division
P.O. Box 3 Filton House
Bristol BS12 7QE
ENGLAND

Northrop Corporation
Aircraft Division
3901 West Broadway
Hawthorne, CA 90250

Pan American World Airways
Pan American Building
ATTN: Mr. John G. Borger
Chief Engineer
New York, NY 10017

North American Rockwell Corporation
Aerospace and Systems Group
ATTN: Technical Library
6633 Canoga Avenue
Canoga Park, CA 91304

British Aircraft Corporation, Ltd.
GPO Box 77, Filton House
ATTN: J. Wallin, Chief Prop. Engineer
Bristol BS99 7AR
ENGLAND

DOT/Federal Aviation Adminstration
Mike Monroney Aeronautical Center
AFS-581
P.O. Box 25082
Oklahoma City, OK 73125

DOT/Federal Aviation Adminstration
Mike Monroney Aeronautical Center
AFS-580
P.O. Box 25082
Oklahoma City, OK 73125

National Transportation Safety Board
Bureau of Aviation Safety
Engineering Division
ATTN: Mr. Martyn V. Clarke, Asst Chief
Washington, DC 20591

British Aerospace PLC
ATTN: M. A. Laceby, Civil Aircraft Div
GPO Box 77, Filton House
Bristol BS99 7AR
ENGLAND

Civil Aviation Authority
ATTN: L. R. Wilson
Brabazon House
Redhill, Surrey
ENGLAND

Hawker Siddley Aircraft
ATTN: Technical Library
Hawsidair, Hatfield
ENGLAND

Ministry of Defense
W. J. Moschini, Engines T1, Room 151
St. Giles Court 1-13
St. Giles High St., London WC2H 8LD
ENGLAND

Bristol Siddeley Engines, Ltd.
Aero Division
ATTN: Mr. Geoffrey Morris
Filton Bristol
ENGLAND

Director
Naval Research Laboratory
ATTN: Library, Code 2029 (ONRL)
Washington, DC 20390

Office of Naval Research
ATTN: N. Basdekas
Washington, DC 20360

Commander
Naval Air Systems Command
AIR-954
Department of the Navy
Washington, DC 20361

NASA Langley Research Center
ATTN: Library
Langley Station
Hampton, VA 23365

The Boeing Company
Commercial Airplane Group
ATTN: Technical Library
Seattle, WA 98124

Avco Corporation
Lycoming Division
ATTN: Technical Library
550 Main Street
Stratford, CT 06497

GM Corporation
Allison Division
ATTN: Technical Library
340 White Rover Parkway
Indianapolis, IN 46296

GM Corporation
Manufacturing Division
Materials and Structures Laboratory
ATTN: Technical Library
Warren, MI 48090

Goodyear Aerospace Corporation
Aero-Structures Marketing
ATTN: Technical Library
Akron, OH 44305

Goodyear Aerospace Corporation
Arizona Division
ATTN: Technical Library
Litchfield Park, AZ 85340

Lockheed California Company
Division of Lockheed Aircraft Corporation
ATTN: Technical Library
Burbank, CA 91503

Massachusetts Institute of Technology
ATTN: Aero Library
Aeroelastic and Structures Research Lab
Cambridge, MA 02139

University of Notre Dame
ATTN: L. H. N. Lee
Department of Aeromechanical Engineering
Notre Dame, IN 46556

The Pennsylvania State University
ATTN: B. W. McCormick
Department of Aerospace Egnineering
233 Hammond
University Park, PA 16802

Battelle Memorial Institute
Columbus Laboratory
ATTN: Technical Library
505 King Avenue
Columbus, OH 43201

Beech Aircraft Corporation
ATTN: Technical Library
9709 East Central
Wichita, KS 67201

Aeronautical Research Association of Princeton
ATTN: Technical Library
50 Washington Road
Princeton, NJ 08540

Garrett Turbine Engine Company
ATTN: Technical Library
402 South 36th Street
Phoenix, AZ 85034

University of West Virginia
ATTN: Technical Library
College of Engineering
Morgantown, WV 26505

Garrett Turbine Engine Company
ATTN: K. K. Sorenson
Starters and Air Turbine Motors
402 South 36th Street
Phoenix, AZ 85034

Garrett Turbine Engine Company
ATTN: D. G. Furst
Auxiliary Power Units
402 South 36th Street
Phoenix, AZ 85034

Garrett Turbine Engine Company
ATTN: Mr. Alvin R. Finklestein
Department 93-7, Adv. Prop. Eng.
402 South 36th Street
Phoenix, AZ 85034

Marquardt Corporation
ATTN: Technical Library
16555 Saticoy Street
Van Nuys, CA 91405

Commanding Officer
U. S. Army Aviation Material Lab
Fort Eustis, VA 23604

U.S. Army Materials Technology Lab
ATTN: Mr. Kenneth Abbott
Chief Engineer, Materials Branch
Watertown, MA 02172-0001

U.S. Army Materials Technology Lab
ATTN: Mr. John DeLuca, SLCMT-MEC
Chief Engineer, Materials Branch
Watertown, MA 02172-0001

Hamilton Standard, Division of UACC
ATTN: Mr. Gerry Moltar
Mechanical Mettalurgist Technical
Staff, Testing and Analysis
Windsor Locks, CT 06096

General Electric Company
CF6 Engine Structures & Contain. Design
ATTN: J. G. Simon
Aircraft Engineering Group
Cincinnati, OH 45215

Lockheed California Company
L1011 Structures
ATTN: Mr. Warren Stauffer
Building 90
Burbank, CA 91503

General Electric Company
Commercial Jet Engine Operation
GE Containment Program
ATTN: Mr. Gordon Oxx, Metallurgist
Cincinnati, OH 45215

General Electric Company
SAED Advanced Applicaitons
1000 Western Avenue
ATTN: Mr. W. A. Harris, Manager
West Lynn, MA 09105

Cornell Aeronautical Lab, Inc.
Applied Physics Department
ATTN: Paul Rosenthal
Head Engineer
Buffalo, NY 14221

ASD (ASQ/ASNNY-QJ)
C-5A Propulsion and Power Division
ATTN: Mr. Phillip H. Evans
Wright-Patterson Air Force Base
Dayton, OH 45433

Cornell Aeronautical Lab, Inc.
ATTN: Dr. Norman S. Eiss, Jr.
Research Mechanical Manager
Applied Physics Department
Buffalo, NY 14221

Air Force Flight Dynamics Laboratory
ATTN: R. M. Bader, FDTR
Wright-Patterson Air Force Base
Dayton, OH 45433

Arnold Engineering Development Center
Headquarters (AFSC)
ARO, Inc.
Arnold Air Force Station
Tullahoma, TN 37389

General Electric Company
Structures Design
ATTN: Technical Library
Cincinnati, OH 45215

Pratt and Whitney Aircraft
of Canada, Ltd.
ATTN: Technical Library
P.O. Box 186
Highgate Springs, VT 05460

Republic Steel Corporation
Special Metals Division
ATTN: Technical Library
410 Oberlin Avenue, SW.
Massillon, OH 44646

Safety Research Information Service
Research Depart., Nat'l Safety Council
ATTN: Ms. Therese A. Quirk
425 North Michigan Avenue
Chicago, IL 60611

Sandia Corporation
ATTN: Information Dist. Division
Albuquerque, NM 87115

Southwest Research Institute
ATTN: Technical Library
8500 Culebra Road
San Antonio, TX 87206

Office of Naval Research
Branch Office
P.O. Box 39
FPO, NY 09510

Douglas Aircraft Company
3855 Lakewood Boulevard
ATTN: Technical Library
MC 36-84
Long Beach, CA 90846

General Electric Company
1000 Western Avenue
ATTN: Technical Library
West Lynn, MA 09105

Hamilton Standard
Division of United Aircraft Corporation
ATTN: Technical Library
Windsor Locks, CT 06096

Director
Applied Technology Laboratory
U.S. Army Air Mobility R&D Lab
SAVDL-EU-TAP
Fort Eustis, VA 23604

Commanding General
U.S. Army Aviation Systems Command
AMSAV-ERD
12th and Spruce Streets
St. Louis, MO 83166

North American Rockwell Corporation
Aerospace and Systems Group
ATTN: Technical Library
6633 Canoga Avenue
Canoga Park, CA 91304

National Gas Turbine Establishment
ATTN: Dr. E. Glenny, Materials Depart.
Pyestock, Farnsborough
Hants
ENGLAND

U.S. Nuclear Regulatory Commission
ATTN: Mr. Ross Chappell
Transportation Branch
Bethesda, MD 20555

Picatinny Arsenal
ATTN: Allen M. Shibley
Specialist
Plastics Technical Evaluation Center
Dover, NJ 07801

DOT/Federal Aviation Administration
Mike Monroney Aeronautical Center
Mr. Dale Crawford, AFS-500
P.O. Box 25082
Oklahoma City, OK 73125

Rolls-Royce (1971) Limited
ATTN: D. J. S. Lancaster
Bristol Engineering Division
P.O. Box 3, Filton, Bristol BS12 7QE
ENGLAND

Bendix Corporation
Utica Division
ATTN: Technical Library
211 Steward Avenue
Utica, NY 13503

Texas A&M University
ATTN: Technical Library
Department of Aerospace Engineering
College Station, TX 77843

Boston University College of
Engineering
ATTN: Technical Library
11C Cummington Street
Boston, MA 02215

The City College of the University of
New York
ATTN: S. B. Menkes
Department of Mechanical Engineering
New York, NY 10031

NASA Lewis Research Center
MS 500-302
21000 Brookpark Road
Cleveland, OH 44135

Air Force Systems Command
Structures Division
Design Criteria Branch (Code FDTE)
Wright-Patterson Air Force Base
Dayton, OH 45433

NASA, Office of Advanced Research
and Technology
ATTN: W. S. Aiken (RAO), Room 6242
800 Independence Avenue
Washington, DC 20546

Canadair Ltd.
ATTN: W. P. Ewanchyna
P.O. Box 6087, Station A
Montreal, Quebec H3C3G9
CANADA

DOT/FAA National Headquarters
Mr. Tom Horeff, AWS-120
800 Independence Avenue, SW.
Washington, DC 20591

Director DuCentre Exp DE LA
Navigation Aerineene
941 Orly, France

Mr. Gale Braden (FAA)
5928 Queenston St.
Springfield, VA 22152

Dr. Hans A. Krakauer
Deputy Chairman, International Airline
Pilots Association Group
Apartado 97
8200 Albufeira, Portugal

Geoffery Lipman, Executive Director
President du Conseil
In'l Found. of Airline Pass Assoc.
Case Postale 462, 1215 Geneve
15 Aeroport, Suisse, Geneva

Richard E. Livingston, Jr.
Director, Aerotech Operations for
the IAPA Group
1805 Crystal Drive, Suite 1112 South
Arlington, VA 22202

*U.S. GOVERNMENT PRINTING OFFICE: 1988--505-068/80101